Nuclear Safety Division

Ines Bredberg
Dominique Ernst
Katarzyna Niedzwiedz
Klaus Hebig-Schubert
Ralf Köhler
Julia Palmes
Eckhard Westermeier

Bundesamt
für die Sicherheit
der nuklearen Entsorgung

Status report on the Use of Nuclear Energy in the Federal Republic of Germany 2022

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**Federal Office
for the Safety of
Nuclear Waste Management
(BASE)**

Wegelystraße 8
10623 Berlin

Phone: 030 184321 0
E-mail: info@base.bund.de
www.base.bund.de

Contributors:
Ines Bredberg
Dominique Ernst
Katarzyna Niedzwiedz
Klaus Hebig-Schubert
Ralf Köhler
Julia Palmes
Eckhard Westermeier

Content

Preface

The Federal Office for the Safety of Nuclear Waste Management (BASE) is the central federal authority for the safe handling of the legacies of nuclear energy use. It performs regulatory, licensing and supervisory tasks in the areas of final disposal, interim storage and the handling and transport of high-level radioactive waste. In particular, it regulates the site selection procedure for a repository for high-level radioactive waste, and ensures public participation. As an independent higher federal authority, BASE is part of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), for which it provides expertise on questions of nuclear waste management and nuclear safety. It conducts and coordinates research in relevant subject areas. Its tasks are based on the following legal foundations:

- Act on the Peaceful Use of Nuclear Energy and Protection against its Hazards (Atomic Energy Act - AtG)
- Act on the Search and Selection of a Site for a Repository for High-Level Radioactive Waste (Site Selection Act - StandAG)
- Act on the Establishment of a Federal Office for the Safety of Nuclear Waste Management (BfnEErrG)
- Act on the Establishment of a Fund for Financing Nuclear Waste Management (Waste Management Fund Act - EntsorgFondsG)
- Act regulating the transition of financing and action obligations for the disposal of radioactive waste of the operators of nuclear power plants (Waste Management Transfer Act)
- Act on transparency regarding the costs of decommissioning and dismantling nuclear power plants and the packaging of radioactive waste (Transparency Act)
- Act on Subsequent Liability for Dismantling and Disposal Costs in the Nuclear Energy Sector (Subsequent Liability Act)
- Act on Protection against the Harmful Effects of Ionising Radiation (Radiation Protection Act - StrlSchG)

In the scope of its statutory tasks, the Federal Office for the Safety of Nuclear Waste Management – or the Federal Office for Radiation Protection (BfS) as it was called until 2016 - has published an annual status report on the use of nuclear energy in the Federal Republic of Germany since 1993. Over the course of time, a report that was initially intended solely for internal use or for the then Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) developed into an important document providing an overview for experts and interested members of the public. Starting in 1998, the report was thus published, too. As of 2009, it was made available as a digital document via the online repository DORIS of the BfS, and since 2020 it can also be found on the BASE website. To reach an international audience, this report is also available in English.

This report, which was correct on 31 December 2022, provides an overview of the use of nuclear energy in the Federal Republic of Germany. The report lists the essential data of all nuclear power plants, research reactors and nuclear supply and disposal facilities. Three nuclear power plants were in operation during the reporting period. Electricity generation by nuclear energy in 2022 totalled approx. 34.7 TWh (2021: 69.1 TWh). The share of nuclear energy in total gross electricity generation was approx. 6 % (2021: approx. 11.8 %)[1] .

[1] Provisional values/ Source: BDEW published in December 2022

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 Technical University of Dresden
ANEX	Facility for zero-power experiments
ANF	Advanced Nuclear Fuels GmbH, French industrial company, main line of business: nuclear technology
AtG	Atomic Energy Act
AVR	Jülich experimental nuclear power plant
AZA	Ahaus radioactive waste storage facility
AZB	Biblis radioactive waste storage facility
AZG	Gorleben radioactive waste storage facility
AZN	Neckarwestheim radioactive waste storage facility
AZO	Obrigheim radioactive waste storage facility
AZP	Phillipsburg radioactive waste storage facility
AZR	Grafenrheinfeld radioactive waste storage facility
AZS	Stade radioactive waste storage facility
AZU	Unterweser radioactive waste storage facility
AZW	Würgassen radioactive waste storage facility
BASE	Federal Office for the Safety of Nuclear Waste Management
BB	Brandenburg
BDEW	German Association of Energy and Water Industries
BE	Berlin
BeHa	Transport preparation building
BER II	Berlin Experimental Reactor II
BfnEErrG	Act to Establish a Federal Office for the Safety of Nuclear Waste Management
BfS	Federal Office for Radiation Protection
BGE mbH	Bundesgesellschaft für Endlagerung mbH
BGZ mbH	BGZ Gesellschaft für Zwischenlagerung mbH
BLG	Fuel Element Storage Facility Gorleben GmbH
BMBF	Federal Ministry of Education and Research
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (until December 2021)
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
BNFL	British Nuclear Fuels Ltd
Bq	Becquerel
BUND	Bund für Umwelt und Naturschutz Deutschland e.V.
BVerwG	Federal Administration Court
BW	Baden-Württemberg
BWR	Boiling water reactor
BY	Bavaria
BZA	Ahaus fuel storage facility
BZB	Biblis storage facility for fuel elements
BZD	Grohnde storage facility for fuel elements
BZF	Brokdorf storage facility for fuel elements
BZG	Gorleben storage facility for fuel elements
BZI	Isar storage facility for fuel elements
BZK	Krümmel storage facility for fuel elements
BZL	Lingen storage facility for fuel elements
BZM	Gundremmingen storage facility for fuel elements
BZN	Neckarwestheim storage facility for fuel elements
BZP	Philippsburg storage facility for fuel elements
BZR	Grafenrheinfeld storage facility for fuel elements

BZU	Unterweser storage facility for fuel elements
CASTOR®	Cask for Storage and Transport of Radioactive Material
CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives
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	Now: Nuclear Technologies GmbH (former: Nuclear Cargo + Service GmbH (NSC))
DBG	permanent operating licence
Destatis	Federal Statistical Office
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 (German Nuclear Fuel Reprocessing Company)
EIA	Environmental impact assessment
ELC	Storage chamber
ELMA	Extended storage facility for intermediate-level radioactive waste
EnBW	Energiewerke Baden-Württemberg AG
EndlSiAnfV	Endlagersicherheitsanforderungsverordnung (repository safety requirements ordinance)
EndlSIUntV	Endlagersicherheitsuntersuchungsverordnung (repository safety investigation ordinance)
EnKK	EnBW Kernkraft GmbH
EntsorgungÜG	Waste Management Transfer Act
E.ON	E.ON Kernkraft GmbH, now PreussenElektra
ERAM	Morsleben disposal site for radioactive waste
ERU	Enriched uranium
ESTRAL	Transport cask store
EVU	Electric power utility
EW	Design document
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
GB	Great Britain
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 (Centre for Materials and Coastal Research 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
HBPI	Main operating plan
HDR	Grosswelzheim hot steam reactor
HE	Hesse
HEU	Highly enriched uranium
HH	Hamburg
HKG	Hochtemperatur-Kernkraftwerk GmbH
HM	Heavy metal
HMGU	Helmholtz Zentrum München, Deutsches Forschungszentrum für Gesundheit und Umwelt GmbH (German Research Center for Environmental Health)
HOBEG	Hochtemperatur-Brennelement Gesellschaft
HTR	High-temperature reactor
HWL	High-active waste storage
IAZ	Industrial application centre
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 section
KWW	Würgassen nuclear power plant

LasmA	Storage facility for radioactive waste and residual materials
LasmAaZ	Storage facility for low- and intermediate-level radioactive waste at the interim storage site of the Kümmel nuclear power plant
LAVA	Facility for storing and evaporating high-level radioactive waste liquids
LAW	Low Active Waste
LEU	Low-enriched uranium
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
MWU	Ministry for Science, Energy, Climate Protection and Environment of the Federal State of Saxony-Anhalt
MV	Mecklenburg-Western Pomerania
MW_e	Megawatt of electrical power
MWh	Megawatt hour
MW_{th}	Megawatt of thermal power
mvK	With a modified cage
MZFR	Multi-purpose research reactor, Karlsruhe
NBauO	Building code of Lower Saxony
NBG	National Citizens' Oversight Committee
NCS	Nuclear Cargo + Service GmbH, DAHER- 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
PFB	Planning approval decision
PG	Process building
PKA	Pilot conditioning plant
PSÜ	Periodic Safety Analysis
PTB	Physikalisch-Technische Bundesanstalt (German national metrology institute)
PuO_2	Plutonium dioxide
PWR	Pressurised water reactor
RAKE	Rossendorf assembly for critical experiments
RBZ-N	Residual waste treatment centre at the Neckarwestheim site
RBZ-P	Residual waste treatment centre at the Phillipsburg site
RFR	Rossendorf research reactor
RP	Rhineland-Palatinate
RPV	Reactor pressure vessel
RRR	Rossendorf ring zone reactor
RSK	Reactor Safety Commission
RWE	Rheinisch-Westfälische Elektrizitätsgesellschaft
SAAS	State Board for Atomic Safety and Radiation Protection (in former GDR)
SAR	Siemens Argonaut reactor
SE	Safe enclosure
SEWD	Disruptive actions or other third-party interventions
SG	Decommissioning licence
SH	Schleswig-Holstein

SL	Saarland
SMUL	Saxon State Ministry for the Environment and Agriculture
SN	Saxony
SNEAK	Fast zero-power facility
SFR	Sodium-cooled fast reactor
ST	Saxony-Anhalt
StandAG	Site Selection Act
STARK	Fast thermal Argonaut reactor
StMUV	State Ministry of the Environment and Consumer Protection of Bavaria
StrlSchG	Radiation Protection Act
StrlSchV	Radiation Protection Ordinance
SUA	Siemens subcritical assembly
SUR	Siemens training reactor
SZL	On-site interim storage facility
TBG	Partial operating licence
TBH-KBR	Transport preparation building at Brokdorf nuclear power plant
TBL	Transport cask storage facility
TEG	Partial construction licence
TG	Partial licence
TH	Thuringia
THTR-300	Thorium high-temperature reactor, Hamm-Uentrop
TRIGA	Training, Research and Isotope Production facility of General Atomics
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
UNS	Independent auxiliary emergency system
UO_2	Uranium dioxide
UTA	Uranium separation work
UVPG	Environmental Impact Assessment Act
VAK	Kahl experimental nuclear power plant
VBA	Lost concrete shield
VDEW	Verband der Elektrizitätswirtschaft (e.V.)
VEK	Karlsruhe vitrification plant
VGB	Technical Association of Energy Plant Operators
VKTA	Radiation Protection, Analysis and Disposal 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)
ZSW	Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg
ZLN	Rubenow Storage Facility North

1 Electrical power generation in Germany

1.1 General Issues

In 2022, a total of approx. 574 TWh of electrical energy was generated in the Federal Republic of Germany (2021: approx. 585 TWh; note: gross generation excluding any power feed, i.e. without electricity exchange balance). Gross power generation in Germany fell by approx. 1.9 % compared to the previous year (cf. Table 1.1)*.
The share of nuclear energy in total gross electricity generation was around 6.0 % (2021: 11.8 %).

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

***	2020		2021		2022*	
	TWh	%	TWh	%	TWh	%
Nuclear energy	64.4	11.3	69.1	11.8	34.7	6.0
Lignite	91.7	16.2	110.4	18.9	117.0	20.4
Hard coal	42.8	7.5	54.9	9.4	66.0	11.5
Mineral oil	4.7	0.8	4.9	0.8	4.6	0.8
Natural gas	94.8	16.7	90.0	15.4	77.5	13.5
Renewables, including	250.8	44.2	237.6	40.5	256.2	44.6
Wind	131.8	23.3	115.0	19.7	124.0	21.6
Water	18.7	3.3	19.4	3.3	17.5	3.0
Biomass	45.4	7.8	45.4	7.8	46.8	8.2
Photovoltaics	48.8	8.6	51.4	8.8	62.3	10.9
Waste (renewable share only)	5.8	1.0	5.7	1.0	5.4	0.9
Geothermal energy	0.2	****	0.2	****	0.2	****
Other conventional energy sources (total) **	18.3	3.2	18.6	3.2	18.0	3.1
TOTAL	567.5	100.0	585.0	100.0	574.0	100.0

* All figures for the year 2022 are provisional, rounded values. Differences between the provisional (estimated) values and the final figures are possible.
** Including non-renewable waste, heating oil, blast furnace gas, not including withdrawals from electricity storage facilities such as pumped or battery storage.
*** all figures have been rounded
**** Very low figure and not specified here
[Source: Destatis, ZSW, BDEW; correct on December 2022]

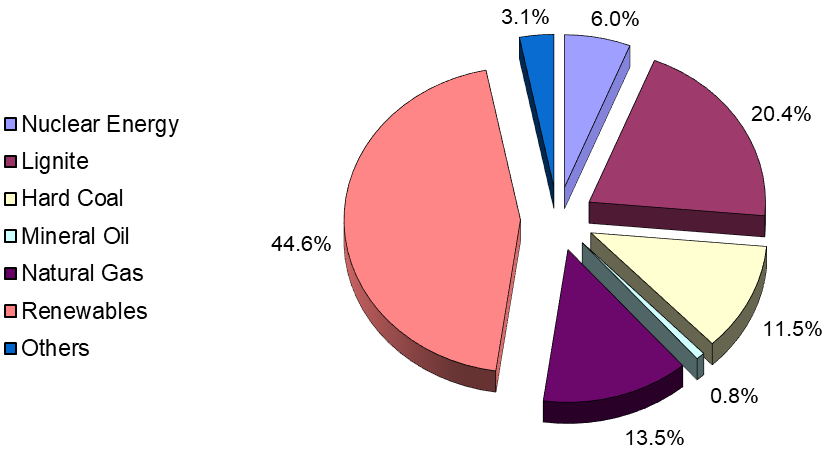


Fig. 1: Shares of the energy sources in the total gross electricity generation in 2022 (basis: 574.0 TWh)

1.2 Phasing out nuclear power generation

The use of nuclear energy for the commercial generation of electricity will be ended in Germany in phases. On 4 December 2022, the operating time of the last three nuclear power plants was extended until 15 April 2023 at the latest.

The end of the operating life of the individual nuclear power plants is defined in the Atomic Energy Act (AtG). The final shutdown of a nuclear power plant is followed by the post-operational phase, during which work is carried out to prepare for decommissioning.

As a result of the reactor accident at the Fukushima Daiichi nuclear power plant in Japan on 11 March 2011, the German government decided in a moratorium dated 14 March 2011 to disconnect all the nuclear power plants in Germany, which had been operative up to and including 1980, from the grid for a temporary period of three months and run them down. 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 off the grid at that time, as was the Krümmel nuclear power plant.

The Reactor Safety Commission (RSK) conducted a safety check on the eight nuclear power plants that were shut down and the nine that were still in operation at the time. Its findings 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 for the commercial generation of electricity in the country.

Figure I.2 in Annex I provides a graphical representation of the development of the use of nuclear energy in Germany over time.

1.2.1 Current nuclear energy legislation in Germany

The 13th Act Amending the Atomic Energy Act of 31 July 2011 stipulated that the last nuclear power plants in Germany should end operation 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 plants had received their first decommissioning licence by the end of 2018.
The decommissioning licence for the Krümmel nuclear power plant is currently in the approval process.

The phase-out of nuclear energy has been gradually continued in line with the Atomic Energy Act. On 27 June 2015, the Grafenrheinfeld nuclear power plant was finally taken off the grid. Power operation for the Gundremmingen B nuclear power plant ended on 31 December 2017. Philippsburg 2 nuclear power plant was finally shut down on 31 December 2019. Power operation at the Brokdorf, Grohnde and Gundremmingen C nuclear power plants ended on 31 December 2021.

According to the 13th amendment to the Atomic Energy Act of 31 July 2011, the last three nuclear power plants in operation, i.e. Isar 2, Emsland and Neckarwestheim 2, were to lose their licence for power operation by 31 December 2022 at the latest. With a further amendment, the 19th Act Amending the Atomic Energy Act of 4 December 2022, the date for the final shutdown of these three plants was postponed to 15 April 2023. Until then, only the fuel elements still available in the respective plant may be used for further power operation.

1.2.2 Generation and transmission of electricity

As early as June 2001, the federal government and the energy supply companies had agreed on a certain quantity of electricity for each nuclear power plant, which the individual facility could still generate related to 1 January 2000 (consensus agreement). This resulted in an operating time of about 32 years for each nuclear power plant, and was laid down in the Atomic Energy Act in April 2002. In 2010, the federal government decided to extend the operating time of the nuclear power plants, which had started operation up to and including 1980, by eight years, and the operating time 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. Under the impact of the reactor accident in Fukushima Daiichi, the federal government decided to end the use of nuclear energy for commercial electricity generation. The Atomic Energy Act, which was subsequently amended in August 2011, once again only contains the electricity volumes stipulated in the earlier Atomic Energy Act in April 2002 for each individual nuclear power plant. The lifetime extension granted in December 2010 was reversed, and the additional electricity quantities cancelled.

The amendment to the Atomic Energy Act on 31 July 2011 marked the first time that a specific shutdown date was legally stipulated for each individual power plant. The Atomic Energy Act also lists the electricity volumes that may still be generated related to 1 January 2000 in column 2 of Annex 3 to Section 7 (1a) (cf. column 2 of Table I.2 in Appendix I); once this quantity has been generated, any authorisation to operate the plant will expire. According to the Atomic Energy Act, it is possible to transfer electricity quantities from one nuclear power plant to another. They may be transferred in whole or in part from one nuclear power plant to another nuclear power plant. Any transfers of electricity volumes must be communicated to the Federal Office for the Safety of Nuclear Waste Management (BASE), and are taken into consideration when registering the electricity volumes. Every year, BASE will publish the quantities of electricity generated and consumed in an annual report in the Federal Gazette pursuant to Section 7 (1c) of the Atomic Energy Act. The annual report for 2022 is included in Annex I in Table I.2.
The following transfers of electricity volumes were made during the 2022 reporting period:

To the Emsland nuclear power plant
- 28 February 2022: 1946.15 GWh from the decommissioned nuclear power plants Gundremmingen Block C (301.43 GWh) and Mülheim-Kärlich (1644.72 GWh)
- 23 September 2022: 60 GWh from the decommissioned nuclear power plant Philippsburg 2

To the Isar 2 nuclear power plant
- 8 and 9 December 2022: a total of 296.00 GWh from the Brokdorf (194.00 GWh) and Grohnde (102.00 GWh) nuclear power plants, both of which have been permanently shut down

On the Neckarwestheim 2 nuclear power plant
- 23 September 2022: 1467.38 GWh from the decommissioned Philippsburg 2 nuclear power plant
- 9 December 2022: 410.00 GWh from the Isar 2 nuclear power plant
- 16 December 2022: 2.308 GWh from the Brokdorf nuclear power plant that is shut down permanently
- 21 December 2022: 100.00 GWh from the Isar 2 nuclear power plant

The 19th amendment to the Atomic Energy Act (AtG) of 4 December 2022 extended the authorisation to operate the last three nuclear power plants, Isar 2, Emsland and Neckarwestheim 2, until 15 April 2023, irrespective of the electricity quantities generated or electricity quantity transfers.

2 Nuclear power plants

This was the status regarding nuclear power plants in Germany on the reporting date at midnight on 31 December 2022:

- 3 nuclear power plants were in operation,[2]
- 3 nuclear power plants had been finally shut down,
- 27 nuclear power plant units were in decommissioning,
- 3 nuclear power plants had been completely decommissioned and released from the Atomic Energy Act and
- 6 nuclear power plant projects had been discontinued.

The Russian Federation's attack on Ukraine on 24 February 2022 represents a caesura for the safe use of nuclear energy in the European framework and the German strategy for energy security and energy production. The subsequent political process in Germany and worldwide led to dramatic changes in national and international economic and energy policy. To ensure the reliability of the electricity supply system in Germany for the winter of 2022/2023, for instance, the legislator postponed the final shutdown of the last three nuclear power plants still in operation, i.e.Isar 2, Emsland and Neckarwestheim 2, originally set for 31 December 2022 in accordance with AtG Section 7 para 1a, to 15 April 2023.

Similar to the previous two years, the reporting year 2022 continued to be affected by the Corona pandemic. The operators ensured nuclear safety at any time, the authorities continued their supervisory work. All German nuclear power plants have pandemic plans that are regularly adapted to the current pandemic situation and its developments. The timely measures taken to protect staff and ensure safe operation were based on these plans.

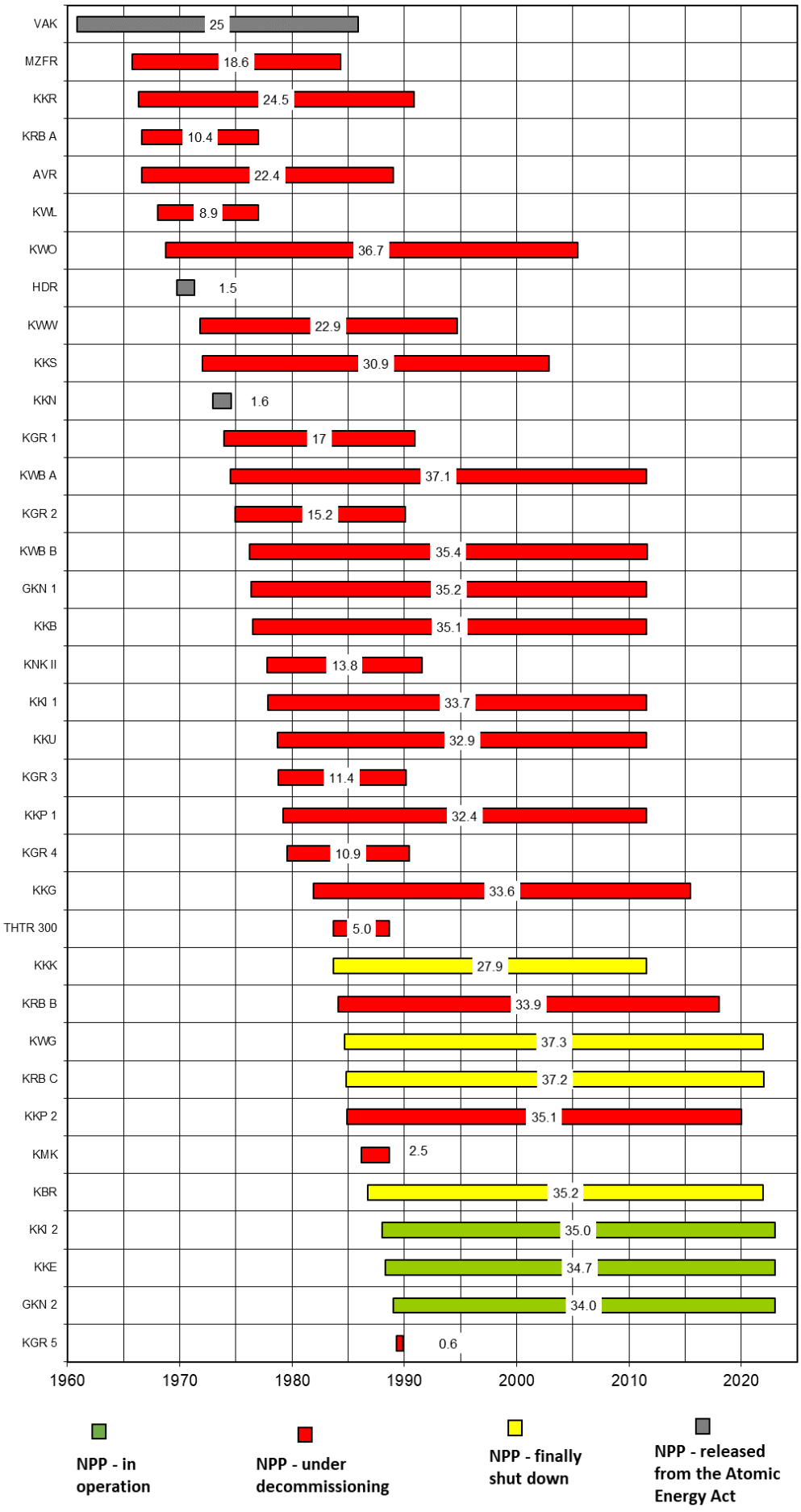
The individual nuclear power plants are described according to their operating status in Chapters 2.1 to 2.5 and in the corresponding tables in Appendix I. An overview is provided in the tabular part in Appendix I. In addition, the following figure shows the operating times of the nuclear power plants in Germany since their initial criticality.

[2] With the amendment to the law, the 19th Act Amending the Atomic Energy Act of 4 December 2022, the date for the final shutdown of the three plants still in operation was postponed to 15 April 2023.

Table 2.1: Nuclear power plants in Germany 2022, as of 31 December 2022 at midnight

Status	Pressurised water-reactor (PWR)		Boiling water-reactor (BWR)		Other		Total	
	Number	MW_e (gross)	Number	MW_e (gross)	Number	MW_e (gross)	Number	MW_e (gross)
In operation	3	4,291	-	-	-	-	3	4,291
Finally shut down	2	2,910	1	1,402	-	-	3	4,312
In decommissioning	16	12,246	8	5,160	3	344	27	19,094
Completely dismantled	-	-	1	16	2	131	3	147
Project discontinued	5	3,320	-	-	1	327	6	3,647

Fig. 2: Operating times of nuclear power plants in Germany in years since first criticality
correct at midnight on 31 December 2022



2.1 Nuclear power plants in operation

Three nuclear power plants were in operation in the reporting year 2022. Table I.3 in Annex I lists the nuclear power plants in operation in the reporting year and their key data.

2.1.1 Availabilities and reportable events

Table 2.2 lists the availabilities and reportable events from German nuclear power plants from 2022. The Incident Reporting Centre at BASE publishes annual reports and monthly reports on reportable events. These reports contain the events in nuclear power plants and research reactors in the Federal Republic of Germany reported in accordance with the Nuclear Safety Officer and Reporting Order (AtSMV), which are registered by the Incident Reporting Centre at BASE.

Details and further information on reportable events are available on the Internet on the BASE homepage at https://www.base.bund.de/DE/themen/kt/stoerfallmeldestelle/ereignisse/ereignisse_node.html.

Table 2.2: Availabilities and number of reportable events of the nuclear power plants in the reporting year 2022

NPP	Time availability* [%]	Work availability* [%]	Labour utilisation* [%]	Number of reportable events
GKN 2	94.43	94.42	90.94	1
KKE	94.88	94.83	91.66	4
CCI 2	97.25	96.88	94.00	1

*Source: International Trade Association for the Generation and Storage of Electricity and Heat (vgbe)

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 by the responsible authorities during the reporting period under the Atomic Energy Act according to Table I.1 (Appendix I) in line with Section 7 of the Atomic Energy Act. Current licensing procedures are also mentioned if they are of particular importance for the plant and licensing status.

The terrorist attacks in the USA on 11 September 2001 drew attention to nuclear facilities as possible targets. Even though the relevant security authorities saw no special risk for nuclear facilities, German nuclear power plants were included in the protection measures against terrorist attacks by commercial aircraft. The goal was, firstly, to make interferences in air traffic more difficult and, secondly, to reduce any potential impact. The set of measures included internal measures at power plants, which were implemented immediately. Furthermore, efforts were made to impede the hit accuracy of targeted terrorist airplane attacks (camouflage through artificial nebulisation). Licences according to Atomic Energy Act Section 7 have already been granted and implemented for some plants.

Baden-Württemberg

Neckarwestheim Nuclear Power Plant Unit 2 (GKN 2)
Neckarwestheim 2 is a pressurised water reactor (PWR), a convoy unit, which was commissioned in 1988 with a capacity of 1,316 MW_e. The current reactor power output of 1,400 MW_e is the result of several thermal and electrical changes to output.

Having been commissioned in December 1988, the Neckarwestheim 2 nuclear power plant is the youngest nuclear power plant in operation in Germany. In accordance with Section 7 (1e) of the Atomic Energy Act, GKN 2 will lose its licence for power operation on 15 April 2023.

EnBW Kernkraft GmbH (EnKK) applied for decommissioning and dismantling of GKN 2 in accordance with 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. [3]

EnBW handed over the Neckarwestheim radioactive waste storage facility (AZN), which is built on the site of the nuclear power plant, to BGZ Gesellschaft für Zwischenlagerung mbH (BGZ) in accordance with the Waste Management Transition Act on 7 December 2020. The residual waste treatment centre (RBZ-N) at the Neckarwestheim site, which was licenced on 17 December 2018 in accordance with Section 7 of the Radiation Protection Ordinance, was commissioned on 2 March 2021.
The storage facility for spent fuel elements was transferred to BGZ mbH on 1 January 2019, and is operated by BGZ mbH as the Neckarwestheim storage facility for fuel elements (BZN).

Bavaria

Isar Nuclear Power Plant Unit 2 (KKI 2)
The Isar unit 2 nuclear power plant is a convoy plant with a PWR. It was commissioned as the first of the three convoy facilities (Isar 2, Neckarwestheim 2, Emsland) in 1988 with a capacity of 1,370 MW_e. The current reactor capacity of 1,485 MW_e results from two thermal and several electrical power output increases. This means that KKI 2 is currently the most powerful nuclear power plant unit in Germany. It will lose its licence for power operation by the end of 15 April 2023 at the latest.

An application for the decommissioning and dismantling of KKI 2 was submitted on 1 July 2019. As part of the environmental impact assessment procedure, a scoping meeting was held on 5 March 2020. The project was announced on 29 July 2021, and the documents were put on public display between 3 September and 2 November 2021. At its own request, Austria received the notification according to Article 3 of the UNECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) and Article 7 of the EIA Directive. The documents were made available for public consultation in Austria from 20 September to 19 November 2021.
An application for a licence pursuant to Section 7 of the Radiation Protection Ordinance (StrlSchV) to handle radioactive materials in the transport preparation building and an application for the construction of a transport preparation building were submitted and granted for the Isar site. The construction of this transport preparation building (BeHa) is proceeding according to plan.
On 1 January 2019, the storage facility for spent fuel elements was transferred to BGZ mbH , who operates it as the Isar storage facility for fuel elements (BZI).

Lower Saxony

Emsland nuclear power plant (KKE)
The Emsland plant is a PWR and one of the three convoy plants in the Federal Republic of Germany. The plant was commissioned in 1988 with a capacity of 1,316 MW_e. The current reactor power of 1,406 MW_e results from a thermal and several electrical power increases. The last power increase of 6 MW took place in May 2014 when the high-pressure turbine was replaced. The Emsland nuclear power plant will lose its authorisation for power operation on 15 April 2023 at the latest.

On 22 December 2016, Kernkraftwerke Lippe-Ems GmbH applied to decommission and dismantle the plant in accordance with Section 7 (3) of the Atomic Energy Act.
On 1 January 2019, the storage facility for spent fuel elements was transferred to BGZ mbH, who will continue to operate it as the Lingen storage facility for fuel elements (BZL).

Kernkraftwerke Lippe-Ems GmbH submitted an application to handle radioactive materials at a new Emsland technology and logistics building (TLE) on 29 August 2018 in line with Section 12 of the Radiation Protection Act. The application was revised with date 8 July 2020 and is currently being processed. The TLE is also to accommodate radioactive materials from the KWL.

[3] After the editorial deadline: The decommissioning and dismantling licence for the GKN 2 nuclear power plant was granted on 4 April 2023.

2.2 Nuclear power plants finally shut down

The following chapter presents the nuclear power plants that have been permanently shut down, but have still not obtained a licence for decommissioning, or did not make use of the decommissioning licence during the reporting period. Table I.4 of Annex I contains the most important data on the nuclear power plants in this category.

Lower Saxony

Grohnde nuclear power plant (KWG)
The Grohnde nuclear power plant is a PWR (pre-convoy) and was commissioned in 1984 with a capacity of 1,365 MW_e. One thermal and two electrical power increases resulted in a reactor power of 1,430 MW_e. The licence for power operation of the nuclear power plant expired on 31 December 2021 pursuant to Section 7 para 1a AtG. The Grohnde nuclear power plant was finally shut down on this date.

An application pursuant to Section 7 (3) of the Atomic Energy Act for the decommissioning and dismantling of the plant in the first dismantling phase (1st SAG) was submitted on 26 October 2017. In connection with this application, an application for the construction of a transport preparation building pursuant to Section 7 of the Radiation Protection Ordinance was submitted on 30 November 2017. The documents are currently being reviewed. As part of the environmental impact assessment, a scoping meeting on both procedures was held on 4 April 2019. The procedure was announced on 28 April 2021 and the documents were made available for public inspection between 6 May and 5 July 2021. The discussion of the objections took place online between 1 October 2021 and 31 December 2021.

On 1 January 2019, the storage facility for spent fuel elements was transferred to BGZ mbH, who operates it as the Grohnde storage facility for fuel elements (BZD).

Schleswig-Holstein

Krümmel nuclear power plant (KKK)
The Krümmel nuclear power plant is the most powerful boiling water reactor (BWR) of the 69 series. The facility was commissioned in 1983 with a capacity of 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 again in June 2009, another short circuit occurred in a machine transformer. The KKK was put into shutdown mode afterwards.
As a result of the amendment to the Atomic Energy Act in 2011, the plant finally ceased power operations (cf. Chapter 1.3), and has been in the post-operational phase since then. The reactor has been defueled. Krümmel nuclear power plant has been free of fuel elements and fuel rods since 11 December 2019. Non-irradiated fuel elements, which have only been contaminated by storage water pools, have already been transported to Sweden for storage. They are due to be shipped to the USA and further processed there at a later date. The decommissioning of a number of systems continued in the reporting year. The disposal of old core scrap (old reactor pressure vessel internals (RPV)) is ongoing.

The operator applied to decommission and dismantle the Krümmel nuclear power plant on 24 August 2015. As part of the environmental impact assessment, a scoping meeting was held on 27 June 2016. The application for decommissioning the plant was specified on 29 September 2017. It included the dismantling of the reactor pressure vessel, the biological shield, other activated plant components and areas around the fuel element storage pool. According to the supervisory authority, the aim is to obtain a decommissioning and dismantling licence in 2023.

An application for a licence pursuant to Section 7 of the Radiation Protection Ordinance to handle radioactive materials in a new storage facility for radioactive waste and residues (LasmAaZ,) was submitted on 13 December 2016. The building application was submitted on 31 March 2017. The building licence for the LasmAaZ was granted on 29 April 2020. The building is currently under construction.

The Krümmel Storage Facility, which has been licensed since 2003, underwent structural upgrading and was handed over to BGZ mbH on 1 January 2019 (new: Krümmel Storage Facility for Fuel Elements (BZK)).

Brokdorf nuclear power plant (KBR)
The Brokdorf nuclear power plant is a PWR (pre-convoy). The plant was commissioned in 1986 with a capacity of 1,380 MW_e. The reactor output was, most recently, 1,480 MW_e. It resulted from two thermal and several electrical power increases. The licence to operate the nuclear power plant expired on 31 December 2021 in accordance with Section 7 paragraph 1a AtG. The Brokdorf nuclear power plant was finally shut down on this date.

On 1 December 2017, the operator applied to the licensing authority for the decommissioning and dismantling of the plant in the first dismantling phase in accordance with Section 7 (3) of the Atomic Energy Act. This application was amended on 24 March 2020. Two dismantling phases are planned. The start of dismantling phase one is planned with fuel elements still present at the plant.
A licence application for the handling of radioactive materials and residues in a new transport provision hall (TBH-KBR) pursuant to Section 7 of the Radiation Protection Ordinance (StrlSchV) was submitted on 8 December 2017. A scoping meeting was held for both projects on 29 January 2019 as part of the environmental impact assessment. The documents were made available for public viewing between 15 June and 17 August 2020. The hearing was held online between 15 February and 15 May 2021.

The Brokdorf Storage Facility, which has been licensed since 2003, was handed over to BGZ mbH on 1 January 2019 (new: Brokdorf Storage Facility for Fuel Elements (BZF)). On 7 July 2022, BASE granted a licence to extend the structural protection of the BZF.

2.3 Nuclear power plants in decommissioning

27 nuclear power plant units were in decommissioning in Germany the reporting year (see Table I.5 in Appendix I). The Hamm-Uentrop high-temperature thorium reactor is the last German nuclear power plant that is being operated in safe enclosure. Dismantling of the other nuclear power plants with the aim of being released from nuclear regulatory supervision will continue.

Baden-Württemberg

Neckarwestheim Nuclear Power Plant Unit 1 (GKN 1)
The Neckarwestheim 1 nuclear power plant is a pressurised water reactor (PWR) and was commissioned in 1976 with a capacity of 855 MW_e. The electrical reactor output amounted to 840 MW_e at the end. The facility was run down on 16 March 2011 by order of the German government. The licence for power operations expired on 6 August 2011 when the Atomic Energy Act was amended (cf. Chapter 1.2.1). The fuel elements were transported to Unit II. The last transport took place in April 2018. Since then, the plant has been free of fuel elements and fuel rods.

The first decommissioning and dismantling licence was applied for on 24 April 2013 and granted on 3 February 2017. Since that time, the inner structures in the reactor pressure vessel have been dismantled and broken up. The demolition of the machine building has started. The second dismantling licence was applied for in a letter dated 21 December 2017, and granted on 12 December 2019. It covers, among other things, the dismantling of the lower part of the reactor pressure vessel, the biological shield, the fuel pool and parts of the reactor safety vessel. Dismantling of the reactor pressure vessel began in August 2021 and was completed in early 2022.
For additional information on the site, see the entry on Neckarwestheim 2 in Chapter 2.1.2 Plant and licensing status.

Philippsburg Nuclear Power Plant Unit 1 (KKP 1)
Like Isar 1, Brunsbüttel and Krümmel, the Philippsburg 1 nuclear power plant is a boiling water reactor (BWR) of the 69 series, and was commissioned in 1979 with a capacity of 900 MW_e. The electrical output when the reactor was shut down in 2011 was 926 MW_e. The licence for power operations expired with the amendment of the Atomic Energy Act on 6 August 2011 (cf. Chapter 1.2.1). All fuel elements and fuel rods were transferred to the KKP storage facility until the end of 2016. Since then, KKP 1 has been free of fuel elements and fuel rods. The cooling towers of the nuclear power plants KKP 1 and KKP 2 were blown up on 14 May 2020. A direct current transformer station (converter) is to be built on the vacated area.

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 (AtG), and the licence was granted on 7 April 2017. Dismantling has begun. The second dismantling licence was applied for in a letter dated 21 December 2017 and approved on 31 July

2020. The application for the second licence covers the dismantling of the biological shield, the fuel element storage pool, the reactor pool and the flood chamber in the reactor building.
Upon its commissioning on 14 April 2020, the newly constructed radioactive waste storage facility Philippsburg (AZP), licensed on 17 December 2018 in accordance with the Radiation Protection Ordinance, was handed over to BGZ mbH in accordance with the Waste Management Transition Act. The residue processing centre (RBZ-P) at the Philippsburg site, also approved on 17 December 2018 in accordance with Section 7 of the Radiation Protection Ordinance, was commissioned on 8 March 2021. The Philippsburg storage facility, which has been licensed since 2003, was handed over to BGZ mbH on 1 January 2019 (new: Philippsburg storage facility for fuel elements (BZP)).

Philippsburg Nuclear Power Plant Unit 2 (KKP 2)
The Philippsburg 2 nuclear power plant is a pressurised water reactor (pre-convoy plant). The plant was commissioned in 1984 with a capacity of 1,349 MW_e. Through several thermal and electrical power increases, the electrical power of the plant was successively raised to a value of 1,468 MW_e. The licence to operate the nuclear power plant expired on 31 December 2019 in accordance with Section 7 Paragraph 1a of the Atomic Energy Act.
EnKK applied to decommission and dismantle KKP 2 in accordance with Section 7 Paragraph 3 of the Atomic Energy Act on 18 July 2016, and updated the application in a letter dated 15 May 2017. The first decommissioning and dismantling licence was granted on 17 December 2019. The reactor pressure vessel was defueled in January 2020 and the fuel rods were transferred to the fuel pool. On 14 May 2020, the cooling towers of the Philippsburg nuclear power plant (units 1 and 2) were blown up. Primary circuit decontamination took place between June and July 2020.

Karlsruhe Multipurpose Research Reactor (MZFR)
The multi-purpose research reactor with a 57 MW_e heavy-water-cooled pressurised water reactor was operated from 1965 to 1984. In addition to electricity generation, it also served to supply heat to the Karlsruhe Nuclear Research Centre through cogeneration. After its final shutdown, a decision was made to dismantle the facility directly and completely. The spent fuel elements were reprocessed at the Karlsruhe Reprocessing Plant (WAK). Since then, dismantling has been taking place in separate partial stages approved under nuclear law (partial decommissioning licences).

The 8th decommissioning licence dated 31 January 2007 allowed for the dismantling of the activated part of the biological shield, the dismantling of all systems and equipment, the 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 of the biological shield. Preparations for the demolition of the so-called D_2O tower, the filter house as well as the auxiliary plant building were started in November 2020, including the removal of residual contamination, radiological preliminary investigations as well as clearance measurements. Once these preparations were completed, demolition work began in March 2021. The reactor building will be decontaminated and cleared on the standing structure in preparation for its planned demolition, and concrete structures on the inside will be removed.

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

Dismantling is due to take place in four independent licensing stages. The nuclear fuel has been removed from the core. The fuel rods were transported to the Neckarwestheim Storage Facility in 15 CASTOR® casks between 27 June and 19 December 2017. Since then, the plant has been free of fuel elements and fuel rods.

The first decommissioning and dismantling licence for final and permanent shutdown was granted on 28 August 2008. The second decommissioning and dismantling licence, issued on 24 October 2011, regulates, among other things, the dismantling of plant components and associated auxiliary systems in the control area (including the reactor cooling system and steam generator) and the operating procedures for continuing the decommissioning process.

On 30 April 2013, the 3rd dismantling licence was issued for dismantling the lower part of the reactor pressure vessel, the reactor pressure vessel fittings, the biological shield and individual structural plant components in the reactor building. The dismantling of the reactor pressure vessel fittings has been completed. The lower part of the reactor pressure vessel has been dismantled. Further work was carried out to dismantle the concrete structures inside the reactor building during the reporting period. The reactor pool and the biological shield were completely dismantled and packaged. The fuel element storage pool was also dismantled.

The fourth 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, mechanical and electrical plant components, the processing of the resulting residual materials, and the treatment of any radioactive waste that may accrue. Within the scope of this licence, building decontamination is currently underway in the reactor building, reactor auxiliary building and emergency building.
As of 1 January 2020, the Obrigheim on-site waste storage facility, now the Obrigheim radioactive waste storage facility (AZO), was transferred to BGZ mbH in accordance with the Waste Management Transfer Act.

Compact sodium-cooled nuclear reactor plant Karlsruhe (KNK II)
The KNK II experimental power plant served to develop breeder technology. The facility contained a 21 MW_e sodium-cooled fast breeder reactor, and was commissioned in 1977. The reactor was finally shut down after completion of the experimental programme 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 at the Interim Storage Facility North.

After the dismantling of the primary shielding was completed as part of the 9th decommissioning licence, the dismantling of the biological shield was prepared. The existing enclosure was dismantled and replaced by a dismantling caisson (protective housing).
This is used to separate the ventilation between the reactor building and the reactor shaft. Work on dismantling the biological shield started in 2019.

The 10th decommissioning licence was granted on 15 July 2021. The approved scope represents the final step towards the complete dismantling of the plant. In addition to the dismantling of remaining facilities, the licence also includes the demolition of all buildings.

According to the operator, the aim of decommissioning is the complete release of the plant from the Atomic Energy Act.

Bavaria

Gundremmingen nuclear power plant Unit A (KRB A)
The Gundremmingen unit A (BWR) went into operation with a capacity of 250 MW_e in August 1966. A characteristic feature of this facility was an internal water-steam separation and steam drying system in the reactor, which was used in a BWR for the first time. Following an incident in 1977, the operator decided in 1980 not to repair the unit for economic reasons, but to shut it down permanently. The last fuel elements were removed from the facility by 1989 and taken for reprocessing. The decommissioning licence according to Section 7 Paragraph 3 of the Atomic Energy Act was granted on 26 May 1983. The plant is being completely dismantled in three phases on the basis of the existing nuclear licences. The dismantling is well advanced. The systems and components in the turbine building and reactor building that are no longer required have been dismantled. The reactor building has been decontaminated, but has not yet been released from nuclear regulatory supervision.

The former technical building (without the reactor building) in unit A has been used as a technology centre since 1 January 2015. Decontamination and waste treatment work for the two units – KRB II B and KRB II C – is being performed there.
The Gundremmingen Storage Facility, which has been licensed since 2003, was transferred to BGZ mbH on 1 January 2019 (new: Gundremmingen Storage Facility for Fuel Elements (BZM)).

The merger of Kernkraftwerk Gundremmingen GmbH with RWE Nuclear GmbH became effective on 13 November 2020. As a result, RWE Nuclear GmbH is now the sole licence holder to the nuclear licences for the Gundremmingen nuclear power plant.

Gundremmingen nuclear power plant Units B (KRB II B) and C (KRB II C)
The Gundremmingen nuclear power plant was designed as a double-unit plant with identical units KRB II B and KRB II C. The two units had boiling water reactors (BWRs) of the 72 series. Both units were equipped with 72-series boiling water reactors (BWRs), which were commissioned in 1984 and 1985, respectively, each with an output of 1,310 MW_e. Due to several electrical capacity increases, the reactor output of Unit B was most recently 1,344 MW_e.

The operator applied to dismantle plant components in unit B on 11 December 2014. KRB II B was permanently shut down according to the Atomic Energy Act on 31 December 2017. The reactor has been defueled. The fuel

elements are located in the fuel element storage pool, and are gradually being transferred to the storage facility. The first licence to decommission and dismantle the Gundremmingen nuclear power plant, phase one, was issued on 19 March 2019. Dismantling of KRB II B has been in progress since that time.

Unit C of the KRB II twin-unit power plant went into operation in 1985 with an electrical output of 1,310 MW_e. A final output of 1,344 MW_e was achieved through gradual technical modernisation. The authorisation to operate the nuclear power plant expired on 31 December 2021 in accordance with Section 7 (1a) of the Atomic Energy Act. The Gundremmingen nuclear power plant was finally shut down on this date.

The dismantling of KRB II is planned in three phases. All sub-projects must be applied for and licenced separately. An initial licence for the 1st partial stage of decommissioning and dismantling the KRB II plant was granted on 19 March 2019. The first phase includes the dismantling of KRB II Unit B. The dismantling of Unit C is then planned for the 2nd partial stage. A second licence to decommission and dismantle plant components of KRB II Unit C was granted on 26 May 2021. Unit C has been undergoing dismantling since 2022. Once nuclear fuel-free operation has been achieved, the remaining systems and plant components can be successively dismantled in the third and final stage. This third licence was applied for on 7 July 2022.

For additional information on the site and the operator, see the entry on the Gundremmingen nuclear power plant Unit A in this section.

Isar Nuclear Power Plant Unit 1 (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 1.2.1). In April 2020, the last CASTOR® cask loaded with fuel elements was brought to the Isar Storage Facility. The Isar 1 nuclear power plant has been free of fuel rods and fuel rods since October 2020. The last defective fuel rod was moved to the fuel element storage pool at the Isar 2 nuclear power plant.

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 (phase 1). 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. On 21 January 2021, the Federal Administrative Court also dismissed the appeal filed. The first decommissioning and dismantling licence is thus final.
An application pursuant to Section 7 Paragraph 3 of the Atomic Energy Act was submitted for the further dismantling of the plant, phase 2 (2nd decommissioning licence), on 31 January 2020. This covers the dismantling of the reactor pressure vessel, the biological shield and the handling of other radioactive materials from the Isar 2 nuclear power plant in the facilities for residual material processing and in buffer storage areas. The dismantling activities of phases 1 and 2 are to be carried out in parallel.

For further information on the site, see the entry on Isar 2 in Chapter 2.1.2 "Plant and licensing status".

Grafenrheinfeld nuclear power plant (KKG)
The Grafenrheinfeld nuclear power plant is a PWR (pre-convoy plant), which was commissioned in 1981 with a capacity of 1,299 MW_e. The last reactor output was 1,345 MW_e and resulted from two electrical power increases. On 15 December 2020, the last loaded CASTOR® container was brought to the storage facility. The plant has been free of fuel elements and fuel rods since December 2020.

An application for the decommissioning and dismantling of the plant was submitted on 28 March 2014. The operator had already taken the unit from the grid on 27 June 2015, before the latest possible shutdown date stipulated in the Atomic Energy Act of 31 December 2015. The first 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 Bavarian State Ministry for the Environment and Consumer Protection issued a relevant statement in July 2019.
The Grafenrheinfeld nuclear power plant is in the first of two dismantling phases. On 17 December 2019, PreussenElektra GmbH submitted an application pursuant to Section 7 (3) of the Atomic Energy Act for the further dismantling of the KKG, Phase 2 (2nd dismantling licence). The application includes the dismantling of the reactor

pressure vessel and the biological shield. The dismantling activities are to take place in parallel dismantling phases.

The staging hall for low- to medium-level radioactive residues built by PreussenElektra GmbH was handed over to BGZ mbH ready for operation on 3 May 2021 and has been operated by BGZ mbH as a radioactive waste storage facility (AZR) since mid-2021.
The Grafenrheinfeld storage facility, which has been licensed since 2003, was handed over to BGZ mbH on 1 January 2019 (new: Grafenrheinfeld storage facility for fuel elements (BZR)).

Brandenburg

Rheinsberg nuclear power plant (KKR)
The Rheinsberg nuclear power plant with an output of 70 MW_e (WWER reactor type) went into service in 1966. It served the independent reactor development of the GDR. The electrical power generated was fed into the national grid. The plant was finally shut down in 1990, after 24 years of operation. The site has been free of nuclear fuel since 9 May 2001; the fuel elements were taken to the Rubenow Storage Facility North (ZLN). Complete dismantling of the plant is planned. The first decommissioning licence was granted on 28 April 1995. The decommissioning work is being carried out successively in partial stages with the appropriate licences.

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

The operator applied for a modification licence on licence I/95 to decommission and partly dismantle KKR according to Section 7 of the Atomic Energy Act on 3 July 2013. This application 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 further procedure” in a letter dated 13 January 2016. The operator submitted an application for a licence pursuant to Section 7 (3) of the Atomic Energy Act in February 2022 to dismantle buildings and building structures of the KKR. The gutting of rooms of the reactor building and the building for special water treatment as well as the connected external tank facility is currently underway.

The decommissioning of the Rheinsberg nuclear power plant also includes the Active Storage Facility for Solid and Liquid Radioactive Residues (ALfR). Demolition work is taking place there on the remaining structures of the container facility and adjacent rooms in a protective enclosure. An application has been filed for salvage of contaminated soil in the groundwater area.

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 cease operations based on the amendment to the Atomic Energy Act in 2011 (cf. Chapter 1.2.1).

Biblis A with a PWR was commissioned in 1974 with an output of 1,204 MW_e. The last valid electrical reactor output was 1,225 MW_e. Biblis nuclear power plant was designed as a double-unit plant. Unit B, also a PWR, started operation in 1976 with an electrical output of 1,300 MW_e. This output was the same to the end of its working life. Unit A has been free of fuel elements and fuel rods since November 2016. Biblis B became free of fuel elements and fuel rods at the beginning of June 2019.

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 first decommissioning and dismantling licence for Biblis nuclear power plant units A and B was granted on 30 March 2017. BUND Hessen e.V. contested the licence for unit A in the courts. The second dismantling licence for unit A was issued on 28 April 2020 and that for unit B on 15 July 2020. The licences cover the dismantling of the reactor pressure vessel, the biological shield and the dismantling of facilities for enclosing the outer containment areas.

The removal of the four steam generators at unit A has been largely completed. 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 focusses on creating the demolition infrastructure. The main coolant lines in unit B have been dismantled, and preparations were made for the removal of the steam generators. The treatment of the dismantled materials is to

take place in unit A. The licence to build a storage facility for low-level and intermediate-level 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 radioactive waste and residues that accrue during the dismantling work at the nuclear power plant site on 5 April 2016. The two storage facilities for low- and intermediate-level waste were transferred to BGZ mbH at the beginning of 2020 (new: Biblis radioactive waste storage facility (AZB 1 and AZB 2)).
The Biblis Storage Facility, which has been licensed since 2003, was handed over to BGZ mbH on 1 January 2019 (new: Biblis storage facility for fuel elements (BZB)).

Mecklenburg-Western Pomerania

Greifswald nuclear power plant (KGR), units 1 to 5
Greifswald nuclear power plant was built based on a decision by the government of former East Germany (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) of the former GDR. It was also decided to decommission unit 5, which had gone critical for the first time in 1989, and the start-up of which had been interrupted by SAAS, the supervisory body at the time. Unit 5 is connected to unit 6 through the double-unit design. Units 6 – 8 were still being built at the time (cf. also Chapter 2.5).

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 (G01) 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. The application GA 08.5 (demolition/demolition of the structural facilities of the special building North I including the linking bridge to the apparatus building North I) of 29 November 2013 is still being processed. EWN is preparing a demolition strategy for this, as clearance at the standing structure is not possible in all areas. EWN GmbH applied to modify the G01 licence and to dismantle/demolish the North II waste air chimney including the air duct between the special building 2 and chimney in accordance with Section 7 Paragraphs 1 and 3 of the Atomic Energy Act on 8 July 2016. The licence was granted on 9 May 2018. The chimney has been fully demolished. A further application for 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.

In a letter dated 28 September 2018, EWN applied for a licence to build and operate a dismantling building in accordance with Section 12 of the Radiation Protection Act. The future dismantling building will serve to dismantle and package large components from the dismantling of the Greifswald and Rheinsberg nuclear power plants in a manner suitable for final storage. The building licence has been granted, and construction has begun.

In a letter dated 29 May 2019, EWN submitted an application to BASE pursuant to Section 6 of the Atomic Energy Act for the storage of storage casks at the transport cask storage facility (ESTRAL) that is to be newly built, and which is to accommodate transport and storage casks of various types currently stored at the ZLN (see Chapter 4.3.3). The hearing took place between 1 and 2 November 2022 in Greifswald.

Lower Saxony

Stade nuclear power plant (KKS)
The Stade nuclear power plant, a PWR with a capacity of 672 MW_e, was in operation from 1972 to 2003. It was finally shut down on 14 November 2003. The then operator E.ON, now PreussenElektra, applied for the direct dismantling of the plant in a letter dated 23 July 2001. The fuel elements were transported to France for reprocessing at the end of April 2005.

The dismantling is planned in five phases. Most recently, phase 4 was approved on 4 February 2011, which includes the further dismantling of the plant and measures to clear buildings and ground surfaces. The nuclear licensing procedure for decommissioning and dismantling was completed with the approval of phase 4. Phase 5 includes the conventional dismantling of the buildings.

All systems and components of the power plant were removed from the controlled area. Dismantling and disposal measures took place in the reporting year. Demolition work continued in the area of the calotte floor.

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 operation 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.

Lingen nuclear power plant (KWL)
The Lingen nuclear power plant, a BWR with a capacity of 252 MW_e, was commissioned in 1968. After 9 years of power operation, the plant was shut down in January 1977 in order to install new steam converters as the old units had been damaged. 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 new, high-temperature gas turbine powered by natural gas. 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 monitored 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) includes the dismantling of the reactor pressure vessel and its internals, the biological shield, the residual demolition work, the decontamination and the release of the facility from nuclear regulatory supervision. The licence for this was granted on 22 July 2021. The third partial project covers the conventional demolition of the building. In autumn 2021, the dismantling of the two steam converters was carried out as a whole. The dismantling of the reactor pressure vessel is being prepared.

Unterweser Nuclear Power Plant (NPP)
Unterweser nuclear power plant went into operation in 1978 with output measuring 1,300 MW_e. It is a nuclear power plant with a PWR. The last electrical reactor output was 1,410 MW_e. With the 13th amendment to the Atomic Energy Act, operations ceased on 6 August 2011 (cf. Chapter 1.2.1).

The fuel elements were removed from the reactor core, and stored at the storage facility for fuel elements. The special fuel rods were packed in CASTOR® casks and also moved to the storage facility. The Unterweser nuclear power plant has been free of fuel elements and fuel rods since 21 February 2019.

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 first licence notice for decommissioning and dismantling (1st SAG) for the Unterweser nuclear power plant (Notice I/2018) was granted on 5 February 2018. Licence Notice I/2021 was issued for partial project 2 of the dismantling process (in particular dismantling of the activated plant components) on 15 July 2021. This means that all the nuclear licensing notices required for dismantling have been issued.
Dismantling and disposal measures, in particular preparatory measures for the removal of the steam converters as a whole, are ongoing.

Underwater dismantling and packing of the RPV internals were completed and the fuel pool and RPV reached a “water-free” status. The segmentation of the RPV bottom section by means of a large band saw system was started.

The Unterweser 2 radioactive waste storage facility (AZU 2) went into operation in July 2020, and was handed over to BGZ mbH in accordance with the Waste Management Transition Act. AZU 1 had already been commissioned in 1981.
The Unterweser storage facility, which has been licensed since 2003, was handed over to BGZ mbH on 1 January 2019 (new: Unterweser storage facility for fuel elements (BZU)).

North Rhine-Westphalia

Jülich Experimental Reactor Working Group (AVR)

The AVR experimental nuclear reactor was an experimental reactor that was exclusively developed in Germany. It was commissioned in 1966 with a 15 MW_e pebble-bed, high-temperature reactor (HTR), and helped the development, which had begun in Germany, of this type of reactor with spherical fuel elements made of graphite, which contained coated particles with uranium and thorium. The AVR 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 a safe enclosure was granted on 9 March 1994. The defueling of the spherical 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 spherical 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 on 23 May 2015 and transported to the reactor vessel storage facility built at the site. 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 of components of the primary circuit has been completed. The decontamination necessary to prepare for concrete demolition work in the protection vessel has also been completed. Dismantling began at the end of August 2020. It is being carried out by radio remote control using a demolition robot.

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

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 shut down 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. Nuclear dismantling was successfully completed in 2014. The clearance measurements in the outdoor area were completed in 2016, and the official clearance notice was issued in December 2017. The approval procedure for the control area buildings continued during the year under review. Interim storage operations also continued for radioactive waste from the Würgassen radioactive waste storage facility (AZW), which was commissioned in 2007 and exclusively stores low and intermediate level radioactive waste from the dismantling and operation of the plant. The low- and intermediate-level radioactive waste stored in the converted building of the Independent Emergency Cooling System (UNS interim storage facility) is to be removed from storage in the next few years, as a joint demolition of all buildings can only be considered once the UNS interim storage facility has been cleared.

Thorium High-Temperature Reactor Hamm-Uentrop (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 then, the fuel assemblies have been removed from the reactor core and taken to the Ahaus storage facility for fuel elements (BZA) in CASTOR® casks. The reactor core has been defueled since 1995. The licence to operate in "safe enclosure" mode (maintenance operations) was granted on 21 May 1997. The facility has been in safe enclosure mode since October 1997. Nuclear dismantling is planned to begin in 2030.

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 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. Dismantling of the steam generators began in October 2018 and was completed in January 2021. Multi-stage dismantling of the reactor pressure vessel has begun.
In addition to dismantling the major components and associated preliminary work, the major focus is on preparation work for the clearance of buildings.

The notice 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 3d under the Atomic Energy Act is designed to regulate the clearance of the buildings in the control area and release the site from supervision under the 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 1.2.1). The facility has been free of fuel elements and fuel rods since 18 February 2018.

The Ministry of Energy Transition, Agriculture, the Environment, Nature and Digitalisation in Schleswig-Holstein granted the licence to decommission and dismantle KKB in response to the application dated 1 November 2012 in line with Section 7 Paragraph 3 of the Atomic Energy Act on 21 December 2018. Initial measures for dismantling the facility were carried out. Dismantling of the RPV has begun, and internals and pipelines have been removed. The second dismantling licence (2nd SAG) was applied for on 8 June 2020 in accordance with Section 7 (3) of the Atomic Energy Act. This covers the further dismantling of plant components of the Brunsbüttel nuclear power plant.

An application to handle radioactive materials at the new storage facility for radioactive waste and residues (LasmA) in line with Section 7 of the Radiation Protection Ordinance (StrlSchV) was made on 5 May 2014. Construction began on 6 September 2018 on the basis of a partial construction licence.

2.4 Nuclear power plants released from the Atomic Energy Act

In the Federal Republic of Germany, three nuclear power plants have so far been completely dismantled and released from the scope of the Atomic Energy Act. Annex I, Table I.6 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 a 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 in 1971 because of distortion on the cladding tubes on the new kind of boiling water superheater 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 were completed by mid-October 1998.

Niederaichbach Nuclear Power Plant (KKN)
The Niederaichbach nuclear power plant, a prototype nuclear power plant with 106 MW_e capacity, was characterised by the use of natural uranium and a heavy water-moderated pressure tube reactor with CO_2 gas cooling. The pressure tube principle was intended to avoid thick-walled pressure vessels required for LWR reactors and to allow reactors of almost any size to be used.

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 both the technical procedure for a full removal and the associated licence procedure under the Atomic Energy Act.

Kahl Experimental Nuclear Power Plant (VAK)
The Kahl experimental nuclear power plant with a 16 MW_e BWR 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 notice 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.

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 Discontinued nuclear power plant projects

The following is a list of nuclear power plants that were planned, but their completion was discontinued after construction had begun. Table I.7 in Annex I provides an overview of these projects.

Mecklenburg-Western Pomerania

Greifswald Nuclear Power Plant (KGR), units 6 to 8
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 as a technical exhibition for visitor tours to demonstrate the reactor technology. The turbine building for the units 5 – 8 was completely emptied 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, a sodium-cooled fast breeder reactor with output measuring 327 MW_e, was built between 1973 and 1991, largely completed and prepared for operation. Even before the fuel elements that had been manufactured were inserted, a decision was made to forego starting the plant in 1991. 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 reprocessing.

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 of 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 for other purposes.

3 Research Reactors

Research reactors are nuclear facilities that are not used for commercial electricity generation. They are used for scientific experiments at research centres and universities etc.
A total of 46 research reactors have to be considered in the Federal Republic of Germany, of which currently (correct on 31 December 2022):

6 research reactors in operation,
3 research reactors finally shut down
6 research reactors in decommissioning and
31 research reactors where decommissioning has been completed. They have been released from the Atomic Energy Act (AtG).

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 is 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

A total of six research reactors were in operation in the Federal Republic of Germany as of 31 December 2022. These include the FRM II (P_{th} =20 MW), the FRMZ (P_{th} =100 kW) and four homogeneous zero-power teaching reactors (P_{th} ≤2 W). In addition to the following information, the most important data on the research reactors in operation can be found in Appendix II, Table II.1.

Munich High Flux Neutron Source in Garching (FRM-II)
The FRM-II is the latest research reactor commissioned in the Federal Republic of Germany. It is a light-water-cooled pool-type reactor with a compact core using highly enriched uranium (HEU) as fuel and heavy water as moderator. With a thermal neutron flux of $8 \cdot 10^{14}$ 1/cm²•s, the facility - with a comparatively low thermal output of 20 MW_{th} - is the most intensive German neutron source for beamline experiments and radiation for scientific, industrial and medical purposes.

Nuclear commissioning and operation at the unit were regulated by the operating licence issued on 2 May 2003. The reactor went critical for the first time on 2 March 2004. Routine operation of the unit was 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 of 30 May 2003, it was originally intended to convert the reactor from HEU to a fuel with a reduced enrichment of no more than 50 % uranium-235 (MEU) by 31 December 2010 at the latest. An amendment was made to the original federal/state agreement of 30 May 2003 on 22 October 2010. This amendment provided for a conversion by 31 December 2018 at the latest. As the practical feasibility of conversion was still not given, the agreement was updated again in December 2020. The aim is to reach a decision on the material variant for the fuel by the end of 2023, and to initiate the approval procedure for the conversion by the end of 2025.

After four fresh fuel elements were delivered in December 2019, FRM II ran its 47th cycle in regular operation from 13 January to 16 March 2020. The 47th cycle was completed as scheduled. Due to COVID preventive measures and a reportable event in May 2020 regarding an exceedance of the licensing values for the discharge of C-14, the start of the 48th cycle was postponed to spring 2021. Yet, the start-up of FRM-II was not possible in 2021 because a defect was detected in the cold neutron source. Another damage in 2022 concerned the compensator of the central unit in the central channel. The necessary manufacturing and replacement of the cold neutron source and the central channel will take several months. The start-up of the reactor is planned for the beginning of 2024 - without the cold neutron source for the time being.

During the 2022 reporting period, the Bavarian State Ministry for the Environment and Consumer Protection (ByStUV) granted the following licences to the operator, the Technical University of Munich (TUM):

- the licence pursuant to Section 7 para 1 of the Atomic Energy Act for the construction and operation of an irradiation facility for uranium targets for the production of molybdenum-99 (Mo-99) (granted on 26 July 2022), and
- the licence pursuant to Section 9 para 1 of the Atomic Energy Act for the handling of nuclear fuels and other radioactive materials in laboratory 2.5.05 at the Industrial User Centre (IAZ) on the FRM II site (granted on 19 September 2022).

TRIGA Mark II Research Reactor at the University of Mainz (FRMZ)
The FRMZ is an open pool-type reactor of the TRIGA Mark II type. It is a light-water cooled and moderated reactor with homogeneous fuel moderator elements made of LEU and zirconium hydride. Nuclear commissioning of the unit took place on 3 August 1965. In continuous operation, the thermal output is 100 kW_{th}, and the thermal neutron flux is $4 \cdot 10^{12}$ 1/ $cm^2 \cdot s$. The reactor can also be operated in pulsed operations for 30 ms with a power peak of 250 MW_{th} and a thermal neutron flux of $8 \cdot 10^{15}$ 1/ $cm^2 \cdot s$. The facility is operated for basic nuclear physics research and, because of the high neutron flux density that can be produced for a short time in pulsed operations, it is particularly suitable for investigating short-lived radionuclides with rabbit systems (fast pneumatic tube).

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/cm3 have been achieved at the FRMZ.

In the reporting year 2022, the facility was operating as intended. The multi-shift operation introduced in 2015 as part of the PRISMA university excellence initiative has been well received by the international research groups and was continued last year in several special operating phases. However, operations were restricted due to the pandemic situation. Further restrictions and scheduled interruptions of operation resulted from adjacent construction measures for the new building of the Institute for Nuclear Chemistry.

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

In the reporting year 2022, the facility was operating as intended. Due to the pandemic situation, teaching appointments could only be offered to a limited extent while complying with hygiene measures.

Siemens Training Reactors (SUR) 100
Three Siemens training reactors are currently still in operation in Germany (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 with polyethylene as moderator. Both materials are pressed together in cylindrical fuel plates in the form of a homogeneous mixture. The reactor core is surrounded on all sides by a graphite reflector. In Germany, the SUR units were mainly commissioned in the 1960s and 1970s. The thermal reactor output measures 100 MW_{th}, and the thermal neutron flux in the central experimental channel is usually $5 \cdot 10^6$ 1/ $cm^2 \cdot s$. Details can be found in Table II.1. The SUR units are mainly used as practical training and teaching devices in the field of nuclear technology.

In the reporting year 2022, all SUR facilities were in operation as intended. Due to the pandemic situation, teaching appointments could only be offered to a limited extent while complying with hygiene measures.

3.2 Research reactors finally shut down

Three research reactors were registered under the heading "Finally shut down" on 31 December 2022. No decommissioning licence had been issued for these reactors yet. Table II.2 in Annex II of the report lists the key data on these reactors.

Berlin Experimental Reactor II (BER II)
The BER II was a pool-type reactor with MTR fuel elements. The thermal output was 10 MW_{th} and the thermal neutron flux was approx. $2 \cdot 10^{14}$ $1/cm^2 \cdot s$. The reactor was commissioned on 9 December 1973, and was mainly used for pure and applied basic research with beamline experiments and to generate radioactive isotopes.
Operating the BER II with fuel elements consisting of low-enriched uranium (LEU) or mixed loads with fuel elements made of highly enriched uranium (HEU) and LEU was approved on 14 June 1994 to reduce the proliferation risk. Following a series of mixed loads, a purely LEU core was built and commissioned for the first time on 7 February 2000.
The operator had submitted an application to decommission and dismantle the Berlin experimental reactor BER II on 24 April 2017. On 11 December 2019, the facility was finally shut down after more than 40 years of operation. The post-operational phase began on 1 January 2020.

In the reporting year 2022, the plant was in post-commissioning operation. The reactor core is fuel-free. The remaining fresh fuel rods were shipped to the manufacturer in France in June 2021. All 66 spent fuel elements are in the storage racks of the transfer pool in the experimental hall. Preparation for decommissioning and handing over as many experimental facilities as possible to other institutes for subsequent use is ongoing.

Research Reactor Geesthacht 1 (FRG-1)
The FRG-1 was an open pool-type MTR reactor with a thermal output of 5 MW_{th} and a maximum thermal neutron flux of approx. $1 \cdot 10^{14}$ $1/cm^2 \cdot s$. It was commissioned with HEU on 23 October 1958. FRG-1 was originally used for research into nuclear ship propulsion. Later on, it was mainly deployed for material research with beamline experiments as well as isotope production and neutron activation analyses.

From 1963 onwards, FRG-1 was operated with the new reactor FRG-2 in a joint reactor building, but in different operating pools. 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 applied even after the licence for decommissioning and partial dismantling of FRG-2 was granted on 17 January 1995 (cf. section FRG-2).

In the course of more than 40 years of operation, the FRG-1 was continually upgraded. 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 also possible to increase the thermal neutron flux by using much denser fuels.

FRG-1 was finally shut down on 28 June 2010. Since then, the unit has been in post-operation under its ongoing valid operating licence. The current focus in the post-operational phase is on the disposal of radioactive waste from operation as a preparatory measure for decommissioning and dismantling the unit.

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 research facilities in Delft (Netherlands) and St. Petersburg (Russia) for further use.

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 to release the unit from supervision under the Atomic Energy Act was made on 21 March 2013. The dismantling of the research reactor is to be carried out under a single decommissioning and dismantling licence pursuant to Section 7 Paragraph 3 of the Atomic Energy Act The application to decommission the research reactor FRG-1 and dismantle the research reactor unit and the hot laboratory was further specified 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 on the premises of the research centre, was included in the procedure as part of the specification of the decommissioning application, and is to be dismantled in a hall that is yet to be built.

An application was made for a licence pursuant to Section 7 of the Radiation Protection Ordinance (StrlSchV) to handle radioactive materials for the operation of a storage facility for low- and intermediate- level radioactive waste (transport preparation building) on the site of the research reactor facility on 6 September 2016. A public hearing was held in 2017. The licensing procedure is ongoing.

Research Reactor Geesthacht 2 (FRG-2)
Like FRG-1, FRG-2 was 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 on 16 March 1963 as a material test reactor, 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, the two reactors were viewed as one research reactor for licensing purposes. 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), in agreement with the Federal Ministry of Research and Technology (now the Federal Ministry of Education and Research - BMBF) and industry, submitted an application to decommission FRG-2 on 28 January 1993, and to partially dismantle the reactor because of the decline in orders for material tests by irradiation. The licence was granted on 17 January 1995. The fuel elements were shipped to the USA by 20 September 2000.

On 21 March 2013, an application was filed 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 to release the facility from the regulatory scope of the Atomic Energy Act. The dismantling of the research reactor unit is due to take place through a single decommissioning and dismantling licence pursuant to Section 7 Paragraph 3 of the Atomic Energy Act. The application to decommission the FRG-1 research reactor and to dismantle the research reactor and the hot laboratory was further specified on 6 September 2016 (cf. FRG-1). The public hearing took place on 21 March 2017. The licensing procedure is ongoing.

3.3 Research reactors in decommissioning

Six research reactors were in decommissioning in Germany at the end of 2022. Table II.3 of Annex II contains the most important data for units in this category.

Karlsruhe Research Reactor 2 (FR 2)
It was the first German research reactor 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 a thermal neutron flux of $1 \cdot 10^{14}$ $1/cm^2 \cdot s$, the FR 2 was used as a neutron source for beamline experiments for basic research as well as for irradiation experiments for fuel rod development and isotope production for medical purposes.

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

After twenty years of operation, FR 2 was finally shut down for economic reasons on 21 December 1981. The fuel elements were handed over to WAK for reprocessing by 22 October 1982. The first of several partial licences for decommissioning, partial dismantling and safe enclosure for at least thirty years was granted on 3 July 1986. Since 20 November 1996, the reactor unit as the remaining part of the facility has been in safe enclosure. Since 1997, the reactor hall has been used for a permanent exhibition on the history of nuclear technology.

The report on the safety review of FR 2 of March 2021 confirmed that the safety requirements for safe enclosure were met. Following safe enclosure, there are plans to dismantle the site for the final removal of the reactor unit. Planning is currently underway. The Ministry for the Environment, Climate and Energy Management of Baden-Württemberg is the responsible licensing and supervisory authority.

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

The unit went into operation in 1957 with LEU and a thermal output of 1 MW_{th}, but had already been converted to HEU by 1960. Over the course of its operating life, the thermal neutron flux was gradually increased from originally $1 \cdot 10^{13}$ $1/cm^2 \cdot s$ to $7 \cdot 10^{13}$ $1/cm^2 \cdot s$; in addition, the thermal output was increased to 2.5 MW_{th} in 1966 and to 4 MW_{th} in 1968, and a beryllium reflector was installed in 1982. Since 1991, the core has been operated as a mixed core and gradually converted from HEU to MEU.

On 14 December 1998, the Technical University of Munich (TUM) applied to decommission the unit so that it could be transferred to an adjacent unit in what was the new FRM-II at the time (Chapter 3.1) in a later procedural stage. The reactor was finally shut down on 28 July 2000, and the 47 remaining fuel rods were shipped to the USA on 3 June 2002.The licence for the dismantling of the reactor facility at FRM Garching pursuant to Section 7 of the Atomic Energy Act (AtG) was granted on 3 April 2014. No dismantling work can be carried out in the reactor building until the ventilation system has been renewed. Planning for this system is currently underway. The dome building of the FRM, known as the Garching nuclear egg, has been placed under a preservation order.

Neuherberg Research Reactor (FRN)
The FRN was a TRIGA Mark III pool reactor with homogeneous fuel moderator elements made of LEU and zirconium hydride. The continuous thermal output of the reactor was 1 MW_{th}, the thermal neutron flux $3 \cdot 10^{13}$ 1/cm^2•s. In pulsed mode, the reactor was able to briefly provide output peaks of up to 2,000 MW_{th} for approx. 10 ms. The facility was commissioned on 23 August 1972, and was used for isotope generation and 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 facility and the dismantling of facility components as well as the safe enclosure of the shielding unit with the former reactor pool. A separate licence dated 24 May 1984 allowed the unit to be kept in a state of safe enclosure.

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

The reactor was decommissioned for economic reasons on 19 December 1995. The remaining fuel elements were shipped to the USA on 28 August 1996. The decommissioning licence for the facility was issued on 2 March 2001. The dismantling of the facility was completed in mid-2004. The radioactive waste and residual materials that had accrued during operation and dismantling were conditioned and transferred to the storage facility set up on the premises of the FMRB for this purpose by May 2005, and this is still subject to supervision under nuclear law. The remaining reactor building and other building areas and floor surfaces have gradually been released from supervision under application of the Atomic Energy Act by 28 July 2005, and can now be used by the PTB for other purposes without any restrictions. The site where the PTB operates the storage facility was transferred by an act of law to the Bundesanstalt für Immobilienaufgaben (BIMA) on 1 January 2012.

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

Nuclear commissioning of the facility 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 in 2008. The North Rhine-Westphalian state authority granted permission to decommission and dismantle the research reactor on 20 September 2012.

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

The decommissioning licence was transferred to the Jülich-based Arbeitsgemeinschaft Versuchsreaktor GmbH on 1 September 2015.The company has been operating under the name "Jülicher Entsorgungsgesellschaft für

Nuklearanlagen mbH (JEN)" since 1 January 2016. This now covers the nuclear operations at the Foschungszentrum Jülich and Arbeitsgemeinschaft Versuchsreaktor (AVR) GmbH.

The dismantling work continued during the reporting period.

Siemens Training Reactor Aachen (SUR-AA)
The Siemens Aachen Training Reactor was operated by RWTH Aachen University. It was built in 1963 by Siemens-Schuckertwerke AG, and went critical for the first time on 22 September 1965. The thermal reactor output was 1.0•E-07 MW_{th}, the thermal neutron flux was approx. $6 \cdot 10^6$ 1/cm^2•s. The research reactor was used for nuclear training and practice purposes, and was also used to carry out experiments in the context of student research projects and diploma theses. The reactor went out of service in 2002. The fuel, cylindrical plates made of a homogeneous mixture of polyethylene as moderator and U_3O_8 with low U-235 enrichment (< 20 %), was transferred to the Technical University of Munich for conditioning and disposal in 2008. In 2010, the operator submitted an application to decommission and dismantle the facility to the competent state authority.

Permission for decommissioning and complete dismantling was granted on 26 June 2020. Due to capacity problems on the part of the operator, dismantling work has not yet started.

3.4 Research reactors released from the Atomic Energy Act

A total of 31 research reactors were decommissioned in the Federal Republic of Germany as of 31 December 2022. They have been released from supervision under the Atomic Energy Act. Table II.4 in Appendix II of this report provides an overview. Some research reactors in this category are reported on in more detail hereafter. The remaining facilities are summarised in a short text.

TRIGA HD I Heidelberg Research Reactor (TRIGA HD I)
The TRIGA HD I was a TRIGA Mark I pool-type reactor with homogeneous fuel moderator elements made of LEU and zirconium hydride. The thermal output of the reactor was 0.25 MW_{th}, the thermal neutron flux $1 \cdot 10^{13}$ 1/cm^2•s. The facility was commissioned on 26 August 1966 as a radiation source for nuclear medical applications.

The reactor was finally shut down on 31 March 1977 due to the construction of a second research reactor (TRIGA HD II, see below) at the German Cancer Research Centre in Heidelberg (DKFZ). The fuel elements were transferred to the new reactor for further use. The licence for decommissioning the facility, granted on 30 June 1980, included the dismantling 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 for dismantling the remaining facility on 25 April 2003, which was approved on 16 January 2006. The dismantling of the facility and the clearance of the building structure were completed during the first half of 2006. TRIGA HD I was released from supervision under the Atomic Energy Act on 13 December 2006. As part of the release procedure, the facility was conventionally demolished in 2009, and the site was cleaned up completely.

TRIGA HD II Heidelberg Research Reactor (TRIGA HD II)
As with TRIGA HD I (see above), TRIGA HD II was a TRIGA Mark I pool-type reactor with homogeneous fuel moderator elements made of LEU and zirconium hydride. The thermal output of the research reactor was also 0.25 MW_{th}, the thermal neutron flux $1 \cdot 10^{13}$ 1/cm^2•s. The reactor went critical for the first time on 28 February 1978, and was used for neutron activation analyses and for the production of short-lived radionuclides for medical purposes in cancer research.

The facility was decommissioned on 30 November 1999 because isotope production had been taken over by an accelerator of the DKFZ and reactor use was subsequently 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 according to Section 7 paragraph 3 of the Atomic Energy Act was granted on 13 September 2004. The unit was completely dismantled during 2005, and released from supervision under the Atomic Energy Act on 13 December 2006.

Frankfurt 1 and Frankfurt 2 Research Reactors (FRF 1 and FRF 2)
The FRF 2 was a light-water-cooled and moderated reactor of the modified type TRIGA with homogeneous fuel moderator elements made of LEU and zirconium hydride. The reactor was installed in the remaining buildings

(reactor hall and reactor unit) of its dismantled predecessor FRF 1 on the basis of the construction licence dated 10 January 1973. FRF 1 had been operated from 10 January 1958 to 19 March 1968 as an L54 homogeneous solution reactor with a thermal output of 0.05 MW_{th}. FRF 2 was intended as a neutron source for basic research in nuclear physics and solid-state physics as well as for activation analyses and isotope production. The Hessian Minister of Education decided on 11 July 1980 not to grant an operating licence, and nuclear commissioning of the ready-to-operate reactor was waived.

A licence to decommission FRF 2 and to dismantle parts of the facility was granted on 25 October 1982. The unused fuel elements of the reactor were transferred to a foreign research reactor (TRIGA MARK II in Ljubljana) in 1981. The residual activity in the facility resulted exclusively from the former operation of FRF 1, and was in a safely enclosed state following the partial dismantling of the facility. After the reactor building had been used as a storage facility for low-level radioactive waste produced by the University of Frankfurt, the demolition 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 cleared.

Research Reactor at the Hannover Medical School (FRH)
The FRH was a TRIGA Mark I pool-type reactor with homogeneous fuel moderator elements made of LEU and zirconium hydride. The thermal output of the facility was 0.25 MW_{th}, the thermal neutron flux approx. $9 \cdot 10^{12}$ $1/cm^2 \cdot s$. Nuclear commissioning of the reactor took place on 31 January 1973. Its use as a neutron source mainly covered neutron activation analysis as well as the production and activation of short-lived radionuclides for medical/biological applications.

Due to changes in the production process for radiopharmaceuticals and a fall in demand, the reactor was finally shut down on 18 December 1996. The fuel elements were shipped to the USA on 9 July 1999. An application for decommissioning and dismantling of facility components was submitted on 22 February 2002, and approved on 8 May 2006. The facility had been completely dismantled and cleared by August 2007. State supervision in accordance with Section 19 of the Atomic Energy Act ended on 13 March 2008.

Jülich Research Reactor 1 (FRJ-1)
The FRJ-1 (MERLIN, Medium Energy Research Light Water Moderated Industrial Nuclear Reactor) was an HEU-fuelled pool-type reactor of British design with MTR-type fuel elements. The last thermal output was 10 MW_{th}, the thermal neutron flux approx. $1 \cdot 10^{14}$ $1/cm^2 \cdot s$. The reactor went into operation 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 value of $1.1 \cdot 10^{14}$ $1/cm^2 \cdot s$ in 1971. This involved, among other things, the use of new fuel elements with a higher uranium-235 mass, and modifications to the primary and secondary circuits for the removal of the thermal output that had been doubled from 5 MW_{th} to 10 MW_{th}.

The FRJ-1 was shut down on 22 March 1985. The fuel rods were removed from the reactor in accordance with the operating licence, and transported to the USA and Great Britain by October 1992. The licence to decommission the facility was granted on 8 June 1995. Gradual dismantling work on the facility was carried out on the basis of further partial and additional licences. Approval to decontaminate the reactor building and its extensions and to meet the requirements for clearance from contaminants with the aim to release the FRJ-1 from the scope of application of the Atomic Energy Act was granted by the licence dated 29 November 2004. This work was completed in the course of 2007, and the facility was released from supervision under application of the Atomic Energy Act on 23 November 2007. The reactor building and its extensions were then dismantled in accordance with conventional regulations so that it was possible to achieve a “green field” state during the course of 2008.

Rossendorf Research Reactor (RFR)
The RFR was a light-water-moderated and cooled tank reactor of Soviet design of the type WWR-S(M). The last thermal output was 10 MW_{th}, the thermal neutron flux approx. $1 \cdot 10^{14}$ $1/cm^2 \cdot s$. The facility was mainly used as a neutron source for isotope production, for activation analyses and for material research, and also for training purposes in the GDR's nuclear energy programme.

The reactor was commissioned on 16 December 1957 with LEU and a thermal output of 2 MW_{th}, which was gradually increased to 10 MW_{th} by 1967, partly through a conversion from LEU to MEU.
The licence to operate the reactor was granted for a limited period of time, and was extended for the last time on 8 October 1990 to 30 June 1991 by the nuclear authority responsible at the time. The reactor was finally shut down

on 27 June 1991. After assuming responsibility as the new nuclear authority, the Saxon State Ministry for the Environment and Agriculture (SMUL) issued a supervisory order according to Section 19 Paragraph 3 of the Atomic Energy Act (AtG) on 28 June 1991 to stop the facility's operations aimed at nuclear fission.
The spent fuel elements were transported to the Ahaus transport cask storage facility in a total of 18 CASTOR® casks between 30 May 2005 and 13 June 2005.

Several partial licences were issued to decommission and dismantle the facility from 30 January 1998 onwards. The licence notice pursuant to Section 7 Paragraph 3 of the Atomic Energy Act was issued for the second amendment of the fourth licence 4653/18 VKTA 04/2 on 9 January 2014. The subject of the amendment was the extension of the previous scope of the licence to cover total dismantling of the residual facility under radiation protection conditions. The operator applied to release the facility from the Atomic Energy Act on 21 June 2018. On 19 September 2019, the State Ministry for the Environment and Agriculture of the Free State of Saxony granted approval for the release of the site of the former Rossendorf research reactor in accordance with Section 33 of the Radiation Protection Ordinance, and certified the release of the facility from nuclear supervision. This concluded the dismantling of the RFR.

Nuclear ship "Otto Hahn" (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 (FDR)" with low-enriched uranium dioxide with a maximum enrichment level of 5.42 % uranium-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 ship went into service on 11 October 1968, and was decommissioned 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 StrlSchV (old version), on 1 December 1980. The reactor vessel was dismantled in the port of Hamburg in June 1981, and transported to the Gesellschaft für Kernenergieverwertung in Schiffbau und Schifffahrt mbH (GKSS), where it has since been stored in a specially built shaft construction (concrete shaft) for a follow-up investigation programme. After the reactor had been removed, the ship was decontaminated, cleared and released from nuclear supervision 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 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. The reactor pressure vessel is to be dismantled in a hall that is yet to be built.

All but 49 irradiated and three unirradiated fuel rods were shipped to the WAK for reprocessing by autumn 1979. 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 Storage Facility North as part of a consolidated transport, along with approximately 2,500 other fuel rods from the Karlsruhe Research Centre, in December 2010.

Further research reactors
The other research reactors have already been dismantled or released from supervision under the Atomic Energy Act. One of these units was not licensed according to Section 7 of the Atomic Energy Act, but Section 9 (SUAK). 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). The individual reactors will not be discussed in detail here. An overview of this category can be found in Appendix II, Tab. II.4.

4 Facilities for nuclear supply and waste management

Annex III contains essential data and information on nuclear fuel supply and disposal in the form of tables, figures and appendices. An overview map of the locations of nuclear supply and disposal facilities is shown in Figure III.

4.1 Uranium enrichment plants

Gronau Uranium Enrichment Plant (UAG)
The Gronau uranium enrichment plant is the only enrichment plant in the Federal Republic of Germany. (cf. Table III.1)
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 this facility.
It went into service in mid- 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 extended UTA-2 plant was commissioned in 2011. The UAG is operated by Urenco Deutschland GmbH, and has a licensed nominal capacity of 4,500 Mg UTA/a. The construction of an indoor storage facility with a capacity of up to 60,000 Mg U_3O_8 was completed in 2014. According to licence 7/6 UAG, the approval of the supervisory authority is required for commissioning and operation. An application has not yet been submitted. The operator stated in March 2022 that an initial storage was not planned before 2026.

4.2 Fuel element factories

One fuel element factory is still operating in Germany (correct on 31 December 2022). All the other facilities have already been entirely dismantled and released from supervision under the Atomic Energy Act (cf. also Tables III.2; III.3).

4.2.1 Fuel element factory in operation

Advanced Nuclear Fuel GmbH (ANF) fuel element factory, Lingen
In the ANF fuel element factory, uranium fuel elements with a maximum content of 5 % uranium-235 are produced for predominant use in light water reactors. Uranium dioxide (UO_2) powder, uranium hexafluoride (UF_6) or externally produced UO_2 pellets are used as the raw material. The process of making fuel elements includes the following steps: conversion of uranium hexafluoride (UF_6) into UO_2 pellets, fuel rod production and fuel element production.

Fuel element production started in January 1979 with externally supplied uranium pellets. 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. ANF submitted an application for the production of hexagonal fuel assemblies for Russian-design nuclear power plants (VVER pressurised water reactors) pursuant to Section 7 para. 1 of the Atomic Energy Act on 10 March 2022, i.e. shortly after the start of Russia's war of aggression on Ukraine. The operator announced its aim to increase the security of supply for the Eastern European nuclear power plants. The fuel element design of the Russian company TVEL is to be used.

729 fuel assemblies were produced in 2022. The authorised storage capacity of uranium hexafluoride is 275 Mg. The UF_6 raw material is stored in containers in a separate storage hall.

A licence pursuant to Section 7 of the Atomic Energy Act was granted on 12 June 2014 to expand the storage areas for nuclear fuel by integrating the storage hall for the storage of radioactive waste that had previously been licensed pursuant to Section 6 of the Atomic Energy Act.

Advanced Nuclear Fuels GmbH (ANF) has submitted an application pursuant to Section 12 (3) StrlSchG for the handling of other radioactive materials in a new service hall, which is to be used for inspections and maintenance work for additional types of fuel element transport casks (also by third parties).

4.2.2 Fuel element factories released from the Atomic Energy Act

Siemens Fuel Fabrication Facility Hanau, MOX unit
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 restart the old unit, except for running it empty.

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 (TG) to dismantle the facility was issued 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 final 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 Fabrication Facility Hanau, uranium unit
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 finally approved decommissioning procedure 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 the radiation exposure they create for individuals in the population is about 10 µSv per calendar year). After the control areas had been dismantled 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 the remediation work was successfully completed in January 2006, the facility was released from supervision under the Atomic Energy Act in May 2006. The groundwater treatment unit of Siemens AG was decommissioned in November 2012. To check the uranium content, the groundwater was monitored at several measuring points until September 2016. The treatment 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 Fabrication Facility Karlstein unit
The plant has been used to produce fuel elements from uranium oxide with a maximum fraction of 4 % uranium-235 since 1966.
As part of the decision to decommission the Siemens facilities in Hanau, the comparatively small facility in Karlstein was also closed. The disposal of all the radioactive operational equipment has been completed. The Siemens fuel fabrication facility, Karlstein unit, was released from supervision under the Atomic Energy Act in March 1999.
Non-nuclear operations continued, and are used for the production of structural components for fuel elements (ANF Karlstein). The Karlstein plant has been a subsidiary of Framatome ANP, later renamed AREVA NP, and since 30 January 2018 named Framatome GmbH, since 2001.

NUKEM-A Fuel Fabrication Facility Hanau
The NUKEM company had produced fuel elements from uranium and thorium up to a uranium-235 enrichment of 94 % for research and material test reactors since 1962.

A first licence to dismantle parts of the unit in the area where the fuel elements were produced was issued on 5 December 1988. NUKEM applied to decommission the entire NUKEM plant on 23 December 1988. The licence for decommissioning was granted on 10 March 1993. Further licences for dismantling the non-safety-relevant parts of the plant followed.

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

All buildings inside the ring fence have since been demolished. Soil remediation was completed in May 2006, and the entire site was released from supervision under the Atomic Energy Act, except for a small area measuring 1,000 m2. A groundwater remediation facility pursuant to Section 19 of the Atomic Energy Act was operated on this area until 2015. The radiological groundwater clean-up was discontinued by a decision of 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 Hanau nuclear site was operated from 1972 to 1988 for the production of spherical fuel elements for high-temperature reactors. The throughput was up to 200,000 fuel elements per year. A total of about 1 million fuel elements were produced. The HOBEG unit was initially operated with several individual licences according to Section 9 of the Atomic Energy Act. These were combined into a temporary overall licence on 30 December 1974. The facility was temporarily shut down on 15 January 1988, and subsequently decommissioned.

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 were sold. The building structures and the surrounding terrain were decontaminated. Following appropriate measurements, the remaining building structures and the associated site were cleared, and released from supervision under the Atomic Energy Act on 18 December 1995.

4.3 Storage of spent nuclerar fuel and HAW

4.3.1 Storage at nuclear power plants

Spent fuel elements are initially stored in the wet pools of the reactor unit at the nuclear power plant, and then at on-site interim storage facilities (cf. Table III.5 in Appendix III).
In line with conditions imposed by 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 across different nuclear power plants.

Of the reactors decommissioned in 2011, all except Krümmel have now received an initial decommissioning licence (see Chapters 2.2 and 2.3). The Biblis A and Philippsburg 1 units were free of fuel elements and rods in 2017 already, the Brunsbüttel and Neckarwestheim 1 reactor plants in 2018, the Unterweser, Biblis Unit B and Krümmel nuclear power plants in 2019, and the Isar 1 and Grafenrheinfeld nuclear power plants in 2020. The fuel elements

in the wet storage pools were completely packed into casks there and placed in the on-site interim storage facilities. As far as the nuclear power plants Brokdorf, Grohnde, Gundremmingen B and C, Isar 2, Philippsburg 2[4] , Neckarwestheim 2 and Emsland are concerned, the aim is to be free of nuclear fuel by the middle of the decade.

Operations at an additional wet storage facility, which had already been built in 1984 in the earthquake-proof emergency building outside the reactor building at the Obrigheim nuclear power plant were approved according to Section 7 of the Atomic Energy Act on 26 October 1998. In 2017, all 342 existing KWO fuel elements from the Obrigheim plant were loaded into 15 CASTOR® 440/84 mvK casks, and transferred to the Neckarwestheim storage facility for storage.

4.3.2 Storage in decentralised fuel storage facilities

The Federal Office for Radiation Protection (BfS) was the responsible licensing authority for storage of 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 came into force, the responsibility for implementing licensing procedures according to Section 6 of the Atomic Energy Act was transferred to the Federal Office for the Safety of Nuclear Waste Management (BASE).

The obligation arising from Section 9a Paragraph 1 of the Atomic Energy Act to ensure the orderly disposal of radioactive waste from operations and decommissioning, safe containment and the demolition of facilities for the fission of nuclear fuel for the commercial generation of electricity was transferred to BGZ after the Electric power utilities (EVU) as waste producers had paid the due amounts to the disposal fund (https://bgz.de/). BGZ is an independent company organised under private law, and its costs are financed via the fund used to finance nuclear waste management. The Federal Republic of Germany, represented by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), is the sole shareholder of BGZ mbH.

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

The storage facility was opened on 23 August 1993. Since 2009, a total of 152 full CASTOR® THTR/AVR casks have been stored at the AVR cask storage facility.

The temporary storage licence expired on 30 June 2013. Since then, the AVR cask storage facility has been operated on the basis of a supervisory order issued by the state of North Rhine-Westphalia.
The storage licence of 17 June 1993 contained the ancillary provision that the licence holder had to provide the nuclear supervisory authority with evidence regarding the further management of the AVR fuel elements by 30 June 2007 at the latest. The FZJ applied for an extension of the storage licence in Jülich in 2007, and specified an extension period of three years 2009.

Furthermore, in 2009, the FZJ applied to the BfS for permission to store the AVR fuel elements at the Ahaus storage facility. A transport licence was applied for in 2010. As a result, the FZJ requested the licensing procedure for the extension of storage in Jülich to be suspended on 16 July 2010. In 2012, the FZJ changed its plans again, and applied to resume the procedure for the continued storage of the AVR fuel elements in Jülich. This has been ongoing since then. The current application is for a new licence for a period of nine years.

In 2013, Gesellschaft für Nuklear-Service mbH (GNS) initially applied for the suspension of the procedure for storing the AVR fuel elements in Ahaus on behalf of the FZJ. In 2014, the FZJ announced that it wanted to pursue the possibility of transporting the fuel elements to the Ahaus transport cask storage facility again. The licence to store the AVR fuel elements at the Ahaus transport cask storage facility was granted on 21 July 2016. The town of Ahaus

[4] After the editorial deadline: The fuel elements of the Philippsburg 2 nuclear power plant have been moved to the interim storage facility for fuel elements.

and a private individual have filed a lawsuit against this licence before the Higher Administrative Court of the State of North Rhine-Westphalia. The case is still pending there.

JEN has also been examining the possibility of transporting the AVR fuel elements to the USA since the middle of 2012. However, according to publicly available information from JEN mbH, this option was abandoned in October 2022 in consultation with the relevant federal and state ministries.[5]

The construction of a new storage facility at the Jülich site is also being considered as an alternative. An application to this effect has not yet been submitted.

Storage Facilities for Fuel Elements (formerly on-site interim storage facilities)
Between 1998 to 2000, the operators of the nuclear power plants applied for licenses to store nuclear fuels in the form of spent fuel elements at on-site interim storage facilities (SZL) for a total of 13 sites. The application for a SZL in Stade was withdrawn following the decision to decommission the nuclear power plant.

As of 1 January 2019, all decentralised storage facilities except for the Brunsbüttel storage facility were transferred to BGZ mbH. With their transfer, all BGZ mbH-owned storage facilities for the storage of nuclear fuel received new, uniform designations. They will henceforth be referred to as storage facilities for fuel elements.

Apart from the nuclear 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 of the federal state concerned. A joint environmental impact assessment was performed as part of the licencing procedures related to the applications from 1999 onwards. This was based on European Directive 85/337/EEC as amended by Directive 97/11/EC, which applied until 16 February 2012, and the Environmental Impact Assessment Act (UVPG). Among other things, the possible effects of the respective project on humans, animals, plants and their habitat as well as on soil, water, air and climate were examined.

In accordance with Section 6 (2) No. 4 of the Atomic Energy Act, the licensing procedure also required examinations as to whether the necessary protection against disruptive measures or other interference by third parties (SEWD) was ensured. Since the terrorist attacks of 11 September 2001, it can no longer be ruled out that air traffic may be misused as a means of attack, despite high security standards. Even though there are no findings that indicate a concrete recent or current danger to stationary nuclear facilities, the effects of a targeted crash of a wide-bodied aircraft onto an interim storage facility were examined in addition to the consideration of acts of terrorism and sabotage as part of the examinations pursuant to Section 6 (2) No. 4 of the Atomic Energy Act (AtG). The examinations showed that, for all scenarios under consideration, the maximum effective dose determined for the reference person at the most unfavourable point of impact was significantly lower than the guideline value of 100 mSv, which has been determined also at legal level in Section 44 Paragraph 2 Sentence 3 of the Atomic Energy Act since September 2021.

The storage facilities for fuel elements 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 initially being used 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, licence 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.

[5] Source: "Zukünftiger Verbleib der AVR-Brennelemente aktueller Stand der Optionen", Jülich Neighbourhood Dialogue, Jülich FZJ, 06.03.2023

Storage of spent fuel elements had been authorised for twelve on-site storage facilities by the end of 2003 (cf. Table 4.1). The Federal Office for Radiation Protection (BfS), which was the responsible licensing authority at that time, had initially granted partial licences for those parts of the application that had been fully examined, with the result that the processing of the applications made in 1998 – 2000 has not yet been completed. The examinations in the context of modification licences for the SZL continued in 2021. The licensing procedures concerned, on the one hand, the use of new cask designs, the possibility of alternative loading options for the spent fuel elements, and the loading of special fuel rods (e.g. defective fuel rods) into special quivers for storage in the casks. On the other hand, the checks on refitting the on-site interim storage facilities for safety reasons continued as part of the licensing procedures. The modification licensing procedure for the storage of special fuel rods in casks for the Neckarwestheim interim fuel storage facility (10th modification licence) and the modification licensing procedures for safety-related retrofitting (4th modification licence) and alternative loading variants (5th modification licence) for the Brokdorf interim fuel storage facility were completed in 2022. In each case, the modification licensing procedures involved general preliminary assessments within the meaning of the Environmental Impact Assessment Act (UVPG) to determine whether an environmental impact assessment was required. This has never been the case so far.

With regard to returning the waste from reprocessing in France and Great Britain, the relevant applications to store the vitrified waste at the storage facilities for fuel elements at Philippsburg, Brokdorf, Biblis and Isar were made on 29 September 2017. According to the application, 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. The first licence to store vitrified waste from Sellafield in CASTOR® HAW28M casks was granted for the Biblis storage facility (BZB) on 19 December 2019. Six CASTOR® HAW28M casks containing waste from reprocessing at Sellafield were put into storage at the BZB in November 2020.

On 13 October 2020, BUND Landesverband Hessen e.V. filed a lawsuit with the Hessian Administrative Court against the 9th modification licence for the interim storage facility in Biblis granted on 19 December 2019, which allowed the storage of HAW vitrified waste coquilles from reprocessing in Sellafield. The plaintiff essentially complains about the lack of an environmental impact assessment, a faulty repair concept for the casks, and the lack of protection of the interim storage facility against various disruptive measures and third-party impacts. The proceedings are still pending.

The return of reprocessing waste agreed with France in 2017 originally provided for a total of five CASTOR® HAW28M casks with vitrified intermediate-level radioactive waste (CSD-B) to be stored at Philippsburg storage facility for fuel elements (BZP). The corresponding licensing procedure was completed in December 2021 with the 9th modification licence for the BZP. In addition, a total of 152 casks with high-pressure compacted, intermediate-level radioactive metal residues (CSD-C) of the reprocessed fuel elements were to be stored in the Ahaus storage facility for fuel elements (BZA). Germany and France agreed on a new solution for taking back radioactive waste in 2021. Instead of taking back intermediate-level radioactive waste, three to five CASTOR® containers with vitrified high-level radioactive waste are to be stored at BZP in the future, analogous to the Biblis, Isar and Brokdorf sites. In addition, 30 empty fuel element transport casks are to be brought to Germany – if necessary, they will be stored temporarily at the BZA. This is intended, in particular, to limit the up to 17 previously planned transports of intermediate-level waste to only one transport of high-level waste, and at the same time avoid delays in returning the waste from France. Accordingly, BGZ mbH has submitted an application dated 28 March 2022 for the storage of up to five CASTOR® HAW28M casks with vitrified high-level radioactive waste at the BZP. BGZ mbH intends to submit the application for the storage of the empty fuel element transport casks in 2023[6]

The city of Philippsburg filed an objection to BASE against the 9th modification licence for the BZP for the storage of five CASTOR® HAW28M casks with solidified intermediate-level radioactive waste (CSD-B) on 23 March 2022. The appeal procedure is still pending.

In June 2013, the Higher Administrative Court (OVG) of Schleswig overturned the licence for the Brunsbüttel SZL following a complaint by local residents. According to the judges, the licensing authority had wrongly determined and evaluated both the necessary level of protection against terrorist impacts in the form of a targeted crash of a commercial aircraft and the risks of the terrorist attack scenario at the SZL with anti-tank weapons. The ruling

[6] After the editorial deadline: The application was submitted to BASE on 26 June 2023.

became legally binding with the decision of the Federal Administrative Court (BVerwG) dated 8 January 2015. Since then, operation of the Brunsbüttel SZL has been based on an order issued by the nuclear supervisory authority of the state of Schleswig-Holstein, which is valid until an enforceable storage licence pursuant to Section 6 of the Atomic Energy Act is granted for the stored nuclear fuel. The re-licensing procedure is currently underway.

Further legal proceedings before the Higher Administrative Court of Lower Saxony against the approval for the SZL Unterweser dated 22 September 2003 were terminated in 2021 through a settlement by mutual agreement.

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 an overview of the respective first licences, the licenced masses of heavy metal (HM) and storage positions, as well as when the facilities started operating (i.e. the first emplacement of a full container) of the on-site interim storage facilities. Further details on these interim storage facilities can be found in Table III.5 in the Annex.

Table 4.1: Storage Facilities for Fuel Elements [7]

Storage Facility for Fuel Elements	Granting of the 1st licence according to Section 6 AtG	HM Mass [Mg]	Total storage positions (used by the end of 2022)	Commissioning date
BZB (formerly: SZL Biblis)	22 September 2003	1,400	135 (108)	18 May 2006
BZF (formerly: SZL Brokdorf))	28 November 2003	1,000	100 (35)	5 March 2007
Brunsbüttel Storage Facility for fuel elements* (formerly SZL Brunsbüttel)	28 November 2003	450	80 (20)	5 February 2006
BZR (formerly: SZL Grafenrheinfeld)	12 February 2003	800	88 (54)	27 February 2006
BZD (formerly: SZL Grohnde)	20 December 2002	1,000	100 (37)	27 April 2006
BZM (formerly: SZL Gundremmingen)	19 December 2003	1,850	192 (115)	25 August 2006
BZI (formerly: SZL Isar)	22 September 2003	1,500	152 (88)	12 March 2007
BZK (formerly: SZL Krümmel**)	19 December 2003	775	65 (42)	14 November 2006
BZL (formerly: SZL Lingen)	6 November 2002	1,250	125 (47)	10 December 2002
BZN (formerly: SZL Neckarwestheim)	22 September 2003	1,600	151 (94)	6 December 2006
BZP (formerly: SZL Philippsburg)	19 December 2003	1,600	152 (92)	19 March 2007
BZU (formerly: SZL Unterweser)	22 September 2003	800	80 (40)	18 June 2007

* The licence for the Brunsbüttel storage facility for fuel elements has been revoked. Storage will be continued on the basis of a supervisory order until a new licence can be utilised.
** With the 4th modification licence for the Krümmel storage facility for fuel elements to extend protection against SEWD, the number of storage spaces was reduced from 80 to 65, and the total thermal output was reduced from 3.0 MW to 2.28 MW at the same time.

4.3.3 Storage in central storage facilities for fuel elements

An overview of the central storage facilities for fuel elements outside nuclear power plant sites is given in Table III.4 in Annex III to this report.

In the case of the storage facilities for fuel elements at Ahaus, Gorleben[7] and the transport cask storage of the Storage Facility North, investigations into the effects of a deliberately induced aircraft crash were performed as part of the investigation into a possible additional condition according to Section 17 of the Atomic Energy Act. The expert's findings showed that no risk to life and health as a result of the release of a considerable amount of radioactive substances are to be expected from a potential, deliberately caused plane crash, and that no radical disaster control measures would be necessary.

[7] With their transfer to BGZ mbH, all BGZ mbH-owned interim storage facilities for the storage of nuclear fuel have been given new, uniform designations.

The Ahaus and Gorleben Transport cask storage facilities were operated by GNS Gesellschaft für Nuklear-Service mbH, a company owned by the energy supply companies, until 30 July 2017. Since 1 August 2017, they have been operated by the newly founded BGZ mbH.

Ahaus Transport Cask Storage Facility (now: Ahaus Storage Facility for Fuel Elements)[7]
The Ahaus transport cask storage facility (now: BZA) was originally designed exclusively as a dry storage facility for spent fuel elements in transport and storage casks of the type CASTOR®. The BZA consists of a storage area I (western storage area) and a storage area II (eastern storage area).
The nuclear licence for the storage of fuel elements from light water reactors according to Section 6 of the Atomic Energy Act for a capacity of 1,500 Mg of heavy metal (HM) was granted on 10 April 1987. Storage operations started in June 1992.

The BZA has a licence for storage of spent spherical fuel elements from the THTR 300 in CASTOR® THTR/AVR 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 as well as in casks of the CASTOR® V/19, CASTOR® V/19 SN06, and CASTOR® V/52 cask types 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 to be 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. In 2005, based on the 3rd amending license for BZA granted by 30 March 2004, 18 transport and storage casks of the type CASTOR® MTR2 loaded with spent fuel elements from the Rossendorf Research Reactor were transferred to BZA for storage.

The district government of Münster granted a licence pursuant to Section 7 of the Radiation Protection Ordinance (StrlSchV) for the temporary storage of other radioactive materials from the operation and decommissioning of German nuclear power plants with a maximum total activity of 10^{17} Bq on 9 November 2009. The radioactive waste can be temporarily stored in the western half of the hall (storage area I) in different cask types made of concrete, cast iron and steel. This waste is later to be transferred to the licenced federal repository, Schacht Konrad near Salzgitter, which is currently under construction.

With a licence dated 17 July 2020, the responsible district government of Münster licenced the continued interim storage of low-level and intermediate-level radioactive waste in storage area I of BZA on the basis of Section 3 (3) of the Radiation Protection Act (StrlSchG) until 31 December 2057.

A total of nine modification licences in accordance with Section 6 of the Atomic Energy Act were also granted (cf. Tab III.4) between 2000 and 2017.

Among other things, the 7th amendment licence of 8 February 2016 approved the refitting of the BZA for safety reasons. As the licence for the AVR cask storage facility expired in 2013 (cf. Chapter 4.3.2), the storage of the AVR inventory at BZA was also approved with the 8th amendment licence of 21 July 2016 in response to the application of 24 September 2009. Based on this licence, a total of 152 CASTOR® THTR/AVR casks can be stored in the eastern half of the hall (storage area II) next to the 305 CASTOR® THTR/AVR casks with THTR fuel elements already stored there. The town of Ahaus and a private person filed a complaint against this licence before the Higher Administrative Court of North Rhine-Westphalia on 12 December 2017. The proceedings are still pending. The 9th amendment licence of 1 August 2017 regulated the transfer of licence ownership of the Ahaus transport cask storage facility from GNS to BGZ mbH.

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 to store this CSD-C waste has been under development since 2012. This waste was initially to be stored in as many as 150 casks. Due to the new solution to return radioactive waste from France as agreed in 2021, the development of the TGC27 has no longer been pursued since 2021 (cf. also Chapter 4.3.2).

In letters dated 2 April 2013 and 3 April 2013, GNS and Brennelement-Ahaus-Zwischenlager GmbH submitted an application for the replacement of the existing storage hall crane to meet the increased requirements according to KTA 3902 Section 4.3, and initially submitted conceptual application documents for this purpose. Since 2020, the application has been supported by more detailed application documents, which are currently being reviewed by BASE.

In a letter dated 30 September 2014, GNS had asked to reopen the nuclear licensing procedure for the storage of spent fuel elements from the Heinz Maier-Leibnitz research neutron source at Munich Technical University (FRM II) at the Ahaus transport cask storage facility. The fuel elements are to be stored in casks of the new type CASTOR® MTR3 in storage area II. In a letter dated 7 May 2020, BGZ also requested to reopen the licensing procedure for storage of the spent fuel elements of the Berlin Experimental Reactor (BER II) of the Helmholtz Centre Berlin for Materials and Energy in casks of the CASTOR® MTR3 type. Compared to the storage of fuel elements of the FRM II, a modified version of the CASTOR® MTR3 with a modified primary lid and a new fuel basket is to be used for the storage of the BER II fuel elements. The storage of spent fuel elements from German research reactors, which has been applied for, is part of the comprehensive joint application of BZA and GNS dated 15 September 1995. A decision has only been made for the fuel elements of the Rossendorf research reactor so far.

Within the framework of the return agreements with France described in Chapter 4.3.2, the storage of 30 empty fuel element transport casks ("end-used casks - EUC") is planned at the BZA. [8]

Gorleben Transport Cask Storage Facility (new: Gorleben Storage Facility for Fuel Elements)[7]
The Gorleben transport cask storage facility (now: BZG) is a dry storage facility for spent fuel elements from nuclear power plants with light water reactors and HAW vitrified waste from reprocessing in transport and storage casks.

Following the application made in September 1980, the nuclear storage licence according to Section 6 of the Atomic Energy Act was granted for a capacity of 1,500 Mg HM on 5 September 1983. The safety report and the summary description were published prior to this, and a public hearing was arranged. The storage facility was put into operation on 25 April 1995.

In a new licence dated 2 June 1995, permission was given not only to extend capacity to 3,800 Mg HM and to store 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 as well as waste containing nuclear fuel and other radioactive materials. The storable activity was limited to $2 \cdot 10^{20}$ Bq. Public participation was arranged prior to this decision.
The 6th modification licence dated 21 June 2018 then granted permission to refit the Gorleben for security reasons.
Five casks with spent fuel elements (1 CASTOR® Ic, 1 CASTOR® IIa, 3 CASTOR® V/19) and 108 casks with HAW vitrified waste (1 TS 28 V, 74 CASTOR® HAW 20/28 CG, 21 CASTOR® HAW 28 M and 12 TN85) had been put into storage at the TBL Gorleben until 2011.
Originally, another 21 casks of the type CASTOR® HAW28M with HAW vitrified waste from the British reprocessing plant, Sellafield Ltd., and another five casks of the type CASTOR® HAW28M with vitrified intermediate-level radioactive waste (MAW vitrified waste) from the reprocessing of spent fuel elements in the AREVA NC reprocessing plant in France were due to be stored in BZG.
Following an amendment to the Atomic Energy Act in combination with the Site Selection Act (StandAG) on 23 July 2013, the storage of these casks at the BZG was ruled out legally. The casks are now to be distributed to interim storage facilities close to the site (cf. Chapter 4.3.2).

In letters dated 5 December 2013 and 12 December 2013, GNS and BLG applied for the extension of the storage licence to include the storage of other radioactive materials according to Section 7 (2) StrlSchV in the BZG. As part of this combined storage, the intention is to use one section of the storage area to store disposable waste, which is to be conditioned beforehand at the site, in an extension building at the Gorleben waste storage facility; this extension still has to be built.

[8] After the editorial deadline: The application was submitted with the application dated 26 June 2023.

Transport cask storage at the Rubenow Storage Facility North (ZLN)
The transport cask storage facility at the Storage Facility North is a dry storage unit for spent fuel elements in transport and storage casks. It is located in Hall 8 of the Storage Facility North at the EWN site. The ZLN is mainly used to store spent fuel elements, nuclear fuel and other radioactive waste from the Rheinsberg and Greifswald reactors.

The licence in accordance with Section 6 of the Atomic Energy Act was granted on 5 November 1999, after a corresponding application had been submitted in April 1993. Approval was given for a capacity of max. 585 Mg HM in max. 80 casks of the type CASTOR® 440/84. The maximum storable activity was limited to $7.5 \cdot 10^{18}$ Bq. A start was made on storing the CASTOR® casks on 11 December 1999.

A total of 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 ZLN by 2011.

In a letter dated 29 May 2019, EWN submitted an application pursuant to Section 6 of the Atomic Energy Act for the storage of the 74 transport and storage casks at the new transport cask storage facility (ESTRAL) to be built to the northeast of the ZLN. In this licensing procedure, the application letter and the application documents relevant for public participation were publicly displayed between 11 February and 11 April 2022 as part of the environmental impact assessment, which includes a formal public participation procedure in accordance with the Nuclear Licensing Procedure Ordinance. The public hearing took place in Greifswald from 1-2 November 2022. More detailed application documents are currently expected for the examination of compliance with the nuclear licensing requirements.

Apart from a licence under nuclear law, the construction and operation of the ESTRAL also requires a building licence, which also includes inspections under nature conservation law, and a licence under water law.

4.4 Storage of radioactive waste and nuclear fuel

4.4.1 Storage of radioactive waste

Low- and intermediate-level radioactive waste is also referred to as radioactive waste with negligible heat generation. This waste is produced during the operation and decommissioning of nuclear facilities.
For the storage of radioactive waste with negligible heat generation from nuclear power plants and the nuclear industry, both central interim storage facilities and decentralised storage facilities at the nuclear power plant sites are available. For waste arising from the use and handling of radioisotopes in research, industry and medicine, the state collection centres operated by the Länder are used as storage facilities.
The central storage facilities for radioactive waste are listed in Table III.6. The decentralised storage facilities for radioactive waste at nuclear power plant sites are addressed directly in the brief descriptions of the plant status of the nuclear power plants in Chapters 2.1 - 2.3 of this report.

4.4.2 State custody of nuclear fuel

In the interests of end-to-end state controls for the location of nuclear fuels, Section 5 Paragraph 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 (BASE) since 30 July 2016; it took over this task from the previously responsible body, the Federal Office for Radiation Protection (BfS).

As a precautionary measure, BASE has rented storage space at the Storage Facility North near Lubmin for smaller quantities of nuclear fuel to be stored in accordance with Section 5 (4) of the Atomic Energy Act, but this space is not currently being used.
If, contrary to expectations, larger amounts of nuclear fuels were to be kept in state custody, they would initially be stored at the local site. BASE 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.
One source of plutonium beryllium is currently in state custody in Germany.

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 (Nukleares Entsorgungszentrum Gorleben) for storage, industrial reprocessing and disposal 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 (formerly AREVA, now Framatome, 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.

Karlsruhe Reprocessing Plant (WAK) dismantling project
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 operation in 1971 under the management of WAK Betriebsgesellschaft mbH. During the time of operation, about 200 Mg of nuclear fuel from a large number of reactors were reprocessed. The uranium and plutonium recovered in the process was delivered to nuclear supply companies for further processing.

Following the abandonment of a large-scale reprocessing plant in Germany, operation was finally halted on 31 December 1990. At the end of the reprocessing operations, the plant consisted of the process building with the reprocessing equipment spent nuclear fuels, the storage buildings with casks and process units for the storage of HAWC, and medium-level liquid waste (MAW), and facilities and buildings to supply media and technical infrastructure. The 1st partial decommissioning licence for WAK was granted on 22 March 1993.

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 HAWC was processed into 123 vitrified receptacles at the Karlsruhe Vitrification Facility (VEK), which had been specially built for conditioning, between September 2009 and June 2010. The subsequent rinsing process produced a further 17 vitrified waste receptacles. When the 140th and final waste receptacle was filled on 25 November 2010, operations at the Karlsruhe vitrification plant were finally halted. The waste receptacles were placed in 5 transport and storage casks of the type CASTOR® HAW20/28, and transported to the EWN GmbH Interim Storage North in Lubmin near Greifswald in February 2011 (cf. Chapter 4.3.3). The low and intermediate-level operational radioactive waste from WAK was conditioned at the Nuclear Research Centre in Karlsruhe. After the end of the emplacement of radioactive waste in the Asse mine at the end of 1978, further conditioned operational waste remained in the WAK facility, where it is still stored today.

The overall concept for decommissioning, dismantling and disposal of WAK is to be achieved in six technically independent stages.
Stage 1: Deregulation measures after decommissioning of WAK
Stage 2: First deconstruction measures in the process building (PG)
Stage 3: Further dismantling of the PG until the controlled area is cleared (including supplementary measures to dismantle the PG).
Stage 4: Deregulation after end of vitrification
Stage 5: Complete dismantling of the LAVA, HWL (main waste storage), VEK and residual facilities.
Stage 6: Conventional building demolition

Stages 1 and 2 have been completed, Stage 3 is well advanced. The measures contained in step 4, including the decommissioning of the former HAWC storage facilities and VEK's process facilities, were completed. Stage 5 involves the dismantling of the HAWC storage facilities and the VEK. There are ten dismantling areas (RB) (RB5.1 to RB5.10), which only partially build on each other. The dismantling areas 5.1 Development of the HWL access and 5.2 Remote assembly of the MAW) storage casks in the HWL room R.6 were completed. RB5.9a and 5.9b, which were licenced under the 24th and 25th decommissioning licences and concerned early dismantling at the VEK and the dismantling of the media and power supply in the VEK, have been completed.

There are two emptied HAWC casks in the “LAVA” (storage cask) and “HWL” (reserve casks) buildings, placed in thick-walled concrete cells that are only accessible remotely because of the high dose rate. Despite having been rinsed several times, solid HAWC residue was detected in the reserve cask (81B21) and in the two LAVA casks after they had been emptied. This solid residue will be recovered when the HAWC storage receptacles are remotely dismantled; this was approved by the 22nd decommissioning licence (RB5.3) 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 (RB5.4) was issued on 14 December 2011. It includes the dismantling of the LAVA high-activity laboratory and the LAVA (hot) cells L3, L4 and L5. The high-activity laboratory has been dismantled in the meantime. The decontamination and dismantling work in cell L4 have been completed. Dismantling work of the facilities in LAVA cells L3 and L5 is currently underway.

An application was made to demolish the residual equipment and to abolish the HWL controlled area (RB5.5) on 12 December 2014. An application to dismantle the LAVA-ELMA pipe duct and to abolish the ELMA control area was also made on 12 March 2015 (RB5.7). Both applications are currently being examined by experts.

The licence to dismantle the facilities in the process cells of VEK (RB5.8) was granted on 6 July 2018, and is in the process of implementation.

Most recently, the 27th licence was issued on 4 March 2021, the 28th licence on 1 June 2021, and the 29th licence for the decommissioning and dismantling of WAK was granted on 14 October 2021. These licences contain amendments to Stage 3 of the overall concept to dismantle the process building, and thus serve the overall dismantling of the WAK plant.

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

This application resulted from a decision made by the heads of the federal and state governments in 1979, which, according to the findings and technology at the time, 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, and required the rapid construction of a reprocessing plant. Another reason was that the Lower Saxony State Premier, Ernst Albrecht (CDU), considered it politically impossible 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. DWK decided to withdraw the building application in December 1989. This marked the end of the procedure.

4.6 Conditioning fuel elements

Gorleben Pilot Conditioning Plant (PKA)
(Cf. Table III.8 in Annex III, too)

To advance methods for direct disposal, a pilot conditioning plant for spent fuel elements and radioactive waste was built at the Gorleben site. This is a multi-purpose facility where, in addition to fuel elements, all types of radioactive waste from nuclear facilities can be transferred or conditioned so that they are suitable for disposal. The facility is designed for a capacity of 35 Mg HM per year.

The 1st partial nuclear 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 of the PKA.

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, stipulating that certain systems and plant components should be operated “cold". 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 (BGZ mbH) was taking over, while GNS (Gesellschaft für Nuklear-Service mbH) was bowing out.

The operator plans to dismantle the PKA as soon as alternative solutions are available for the currently relevant functions of the plant.

4.7 Disposal

In Germany, all low-, intermediate- and high-level radioactive waste is to be emplaced in deep geological formations and safely disposed of there. This is intended to ensure safe containment of radionuclides over long periods of time and isolation of this waste from the biosphere. Furthermore, the disposal issue must be solved in a way that is intergenerationally equitable. Deep geological repositories are recognised internationally as the safest treatment for radioactive waste and spent fuel. The overall responsibility for disposal lies with the BMUV. The Bundesgesellschaft für Endlagerung mbH (BGE mbH) is the implementing agency for all radioactive waste repository projects in Germany. Nuclear regulatory supervision is exercised by BASE.

There are currently three projects for low and intermediate level waste in Germany. The Konrad repository is currently under construction, and is scheduled to start operation and receive low- and intermediate-level radioactive waste from 2027 onwards[9]. The Morsleben disposal site for radioactive waste (ERAM) was established by the former GDR and is currently in the planning stage for decommissioning. Waste is to be retrieved from the Asse II mine because its stability is at risk (cf. chapter 4.7.2).

The high-level radioactive waste produced in Germany from the peaceful use of nuclear energy must also be safely contained in a deep geological repository. This waste includes spent fuel elements and waste from reprocessing. Owing to the high activity of the radiological inventory, all these waste materials generate and release heat. Due to the relaunch of the repository site selection procedure within the framework of the moratorium on the exploration of the Gorleben salt dome, the legislator established a new participatory, science-based, transparent, self-

[9] This information was included in the report after the editorial deadline. Source: BGE mbH report " Konrad auf der Zielgeraden - Stand der Fertigstellung des Endlagers Konrad", as of 12 June 2023

questioning and learning procedure to determine the site with the best possible safety for a disposal facility through the amended Act on the Search and Selection of a Site for a Final Repository for High-Level Radioactive Waste (Site Selection Act - StandAG) in 2017. The site selection procedure is divided into three phases. At the end of each phase, a decision will be made by the Bundestag.

4.7.1 Status of the site selection procedure for a repository for high-level radioactive waste

Phase 1 of the site selection procedure is currently underway. As the project implementer, the privately organised Bundesgesellschaft für Endlagerung mbH (BGE mbH), whose sole shareholder is the Federal Republic of Germany, submitted the "Interim Report on Sub-Areas" to the supervisory authority, the Federal Office for the Safety of Nuclear Waste Management (BASE). It was published on 28 September 2020. In this report, BGE mbH outlines areas which are deemed to offer favourable geological conditions for the safe final disposal of high-level radioactive waste. It has identified a total of 90 sub-areas with "favourable geological conditions". All three host rocks designated as potentially suitable in the Site Selection Act (StandAG) (rock salt, clay rock, crystalline rock) are represented. The Interim Report on Sub-Areas excluded the Gorleben salt dome from the search for a repository site for geological reasons.

The publication of the interim report was also the starting signal for the first legally stipulated public participation format: The Sub-Areas Conference. The kick-off event took place on 17 and 18 October 2020. This was followed by three consultation meetings until August 2021. As an additional service, BASE also set up an online participation platform on 18 October 2020. This made it possible to address comments, criticism or questions about the interim report irrespective of the conference dates. BASE made sure that all such submissions were collected, published, and handed over to the conference for the consultation meetings, and to BGE mbH following the conclusion of the conference.

Following further processing steps, BGE mbH will propose siting regions for surface exploration from within the sub-areas. The assessment of the regions during phase 1 will be based exclusively on existing data. Geoscientific investigations will then be carried out during phases 2 and 3. The proposals of BGE mbH will be reviewed by BASE at the end of each phase. The siting decision at the end of phase 3 will be made by the legislator.

At the end of October 2022, BGE mbH presented a first detailed estimate of the time required that outlined the schedule for the individual phases and steps of the site selection procedure. The focus of this estimate is on BGE mbH's own activities. The statutory tasks of other stakeholders (e.g. examination by BASE, work of the regional conferences, legislation) are only depicted in a very general manner. According to this, the site selection procedure will not be completed before 2046 and, in a worst-case scenario, not until 2068. After reviewing the report, BASE does not consider the time horizons mentioned by BGE mbH to be realistic and therefore advocates a holistic reflection process that will consider the interactions with other areas of nuclear waste management, draw conclusions for the site selection procedure and identify adaptation needs.

4.7.2 Construction, operation and decommissioning of repositories

KONRAD repository

The Konrad repository is located in Salzgitter in Lower Saxony. It is the first repository in Germany to be licensed under nuclear law. The licence for the construction and operation of the repository has been in place since 2002. The former iron ore mine is currently being converted into a repository.

The Konrad mine, consisting of Shaft 1 and 2, 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 began in 1982, was concluded by the planning approval decision (PFB) of 22 May 2002. The pending lawsuits against the PFB were rejected by the Higher Administrative Court in Lüneburg in March 2006, and 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 then, the Konrad mine has been converted and expanded into a repository. 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. On 27 May 2021, the environmental organisations BUND Lower Saxony and NABU Lower Saxony submitted applications to the Lower Saxony Ministry for the Environment, Energy, Construction and Climate Protection (NMU) for the cancellation of the PFB, and for an immediate halt to construction. At the time of writing, the NMU had not yet decided on these applications.

BGE mbH submitted an updated schedule for the construction of the Konrad repository on 13 March 2018, this envisaged the completion of the building work (conclusion of commissioning phase B) during the first half of 2027. [10]

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

Morsleben Disposal Site for Radioactive Waste (ERAM)

The Federal Republic of Germany took over responsibility for the Morsleben disposal site for radioactive waste (ERAM), which had been established by the East German government in the former Bartensleben potash and rock salt mine, through the Unification Treaty signed in 1990. The permanent operating licence was legally transferred to the Federal Office for Radiation Protection (BfS) in 1990. The operator responsibilities for the disposal facility were transferred to BGE mbH on 25 April 2017.

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. Approx. 14,432 m^3 of low-level and intermediate-level radioactive waste 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 ERAM.

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. A final decision to stop using the site to store any radioactive waste was made on 12 April 2001, which means that no radioactive waste has been accepted for disposal since then. 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, third-party radioactive waste.

The application made by the BfS on 13 October 1992 to what is now the Ministry of Science, Energy, Climate Protection and the Environment of Saxony-Anhalt (MWU) to continue operation of ERAM was restricted by the BfS to decommissioning ERAM on 9 May 1997. The planning approval procedure not only covers the decommissioning, but also the disposal of the radioactive waste temporarily stored at the facility at this time and the disposal of any operating radioactive waste that accrues during the decommissioning process.

BGE mbH 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 MWU.

[10] Information received after the editorial deadline: As of 12 June 2023, BGE mbH has adjusted its timetables. Accordingly, completion of the Konrad repository is planned for the end of 2029. Commissioning will subsequently take place in several phases before storage operations can begin.

See also BGE mbH press release of 13 June 2023.

ASSE II mine

The Asse II mine near Wolfenbüttel is a potash and rock salt mine that is about 100 years old. 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 BGE mbH 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 respectively. The Mining Act, particularly the requirement for operating plans, must 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 emplacement chamber into the biosphere and into human beings.

Before the retrieval can begin, a salvage shaft and a retrieval mine must be built. Furthermore, a conditioning plant and an interim storage facility ready to receive the waste must be put into operation. In 2020, BGE mbH published documents on the planned procedure for retrieval and the planned licensing structure. In December 2020, the Lower Saxony Ministry for the Environment, Energy, Building and Climate Protection held an initial application conference on the licensing procedure, with the involvement of other public bodies. In preparation for retrieval, BGE mbH initiated a regional planning procedure with the Lower Saxony Ministry of Agriculture. An application conference was held in July 2022. Also in July 2022, the Lower Saxony Ministry for the Environment, Energy, Construction and Environmental Protection approved the inspection of the storage chamber 8a/511 (MAW chamber) for the purpose of a remotely executed investigation of the storage chamber. In addition, BGE mbH carried out extensive preparations for the drilling of the storage chamber 12/750 as part of the fact-finding process in 2022.

Annexes - Overview

Annex I - Nuclear power plants

Correct on 31 December 2022

Table I.1: Licensing and supervisory authorities of the federal government and the Länder for the storage of nuclear fuels pursuant to Section 6 of the Atomic Energy Act and facilities pursuant to Section 7 of the Atomic Energy Act

	Authority for licences according to Section 6 AtG	**Supervisory authorities pursuant to Section 19 in conjunction with Section Section 6 AtG**
	Federal Office for the Safety of Nuclear Waste Management	Regulatory authorities of the Länder
State	Licensing authority for units according to Section 7 AtG	Supervisory authorities pursuant to Section 19 in conjunction with SectionSection 6 and 7 of the Atomic Energy Act. SectionSection Sections 6 and 7 AtG
Baden-Wuerttemberg (BW)	Ministry of the Environment, Climate and Energy Management in agreement with the Ministry of the Interior, Digitalisation and Municipalities	Ministry for the Environment, Climate and Energy Management Baden-Württemberg
Bavaria (BY)	Bavarian State Ministry for the Environment and Consumer Protection	
Berlin (BE)	Senate Department for the Environment, Mobility, Consumer and Climate Protection	
Brandenburg (BB)	Ministry of Social Affairs, Health, Integration and Consumer Protection	
Bremen (HB)	Senator for Climate Protection, Environment, Mobility, Urban Development and Housing in consultation with the Senator for Health, Women and Consumer Protection	
Hamburg (HH)	Authority for the Environment, Climate, Energy and Agriculture	
Hesse (HE)	Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection	
Mecklenburg-Western Pomerania (MV)	Ministry for Climate Protection, Agriculture, Rural Areas and Environment	
Lower Saxony (NI)	Lower Saxony Ministry for the Environment, Energy and Climate Protection	
North Rhine-Westphalia (NW)	Ministry of Economy, Industry, Climate Protection and Energy of the State of North Rhine-Westphalia	
Rhineland-Palatinate (RP)	Ministry for Climate Protection, Environment, Energy and Mobility	
Saarland (SL)	Ministry for the Environment, Climate, Mobility, Agriculture and Consumer Protection of Saarland	
Saxony (SN)	Saxon State Ministry for Energy, Climate Protection, Environment and Agriculture	
Saxony-Anhalt (ST)	Ministry of Science, Energy, Climate Protection and Environment of the State of Saxony-Anhalt	
Schleswig-Holstein (SH)	Ministry for Energy Transition, Climate Protection, Environment and Nature of the State of Schleswig-Holstein	
Thuringia (TH)	Thuringian Ministry for the Environment, Energy and Nature Conservation	

Table I.2: Electricity quantities - annual reporting 2022 In German only, published in the Federal Gazette

Bekanntmachung gemäß § 7 Absatz 1 c Atomgesetz (AtG) - Jahresmeldung 2022 -							
Vom 1. Januar 2000 bis 31. Dezember 2022 erzeugte, übertragene und verbleibende Elektrizitätsmengen [GWh netto] gemäß § 7 Absatz 1a Anlage 3 Spalte 2 AtG							
Kernkraftwerk	Elektrizitätsmenge ab 1. Januar 2000	1. Januar 2000 bis 31. Dezember 2019	Summe 2020	Summe 2021	Summe 2022	Elektrizitäts-mengen übertragen bis 31. Dezember 2022	verbleibende Elektrizitäts-menge
1	2	3	4	5	6	7	8
Isar 2[14) 15) 21) 25) 30) 33) 34) 36)]	231210,00	227282,88	11030,83	11421,16	11610,82	30193,11	57,42
Emsland[11) 31) 32)]	230070,00	217494,86	10836,45	10779,48	10665,36	19706,15	0,00
Neckarwestheim 2[29) 32) 34) 35) 36)]	236040,00	207487,38	10415,99	10459,26	10435,40	3979,69	1221,66
Summe	**697320,00**	**652265,12**	**32283,27**	**32659,90**	**32711,58**		1279,08
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) 11) 14) 22) 26) 31)]	107250,00					-81350,00	25900,00
Neckarwestheim 1	57350,00	57350,00					0,00
Isar 1[12)]	78350,00	76325,88				-2024,12	0,00
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[23)]	47670,00	36670,33				-3666,56	7333,11
Unterweser[5) 6) 7) 8) 9) 12)]	117980,00	106777,14				-11202,86	0,00
Philippsburg 1[2) 10)]	87140,00	73185,87				-13954,13	0,00
Grafenrheinfeld[6) 12)]	150030,00	150283,19				253,19	0,00
Krümmel[13) 15) 16) 17) 19) 20) 21) 23) 24) 25) 27) 29)]	158220,00	69974,89				-62222,55	26022,56
Gundremmingen B[4) 5) 7) 18)]	160920,00	179072,53				18152,53	0,00
Philippsburg 2[10) 28) 32)]	198610,00	205391,86				6781,86	0,00
Grohnde[12) 13) 17) 20) 24) 33)]	200900,00	207673,24	9909,60	10492,41		27175,79	0,54
Gundremmingen C[4) 5) 8) 9) 18) 22) 26) 31)]	168350,00	197430,53	8710,13	10855,38		48646,04	0,00
Brokdorf[16) 19) 23) 27) 28) 33) 35)]	217880,00	212376,52	10015,11	11436,58		15948,69	0,48
Gesamtsumme	**2623310,00**	**2403700,27**	**60918,11**	**65444,27**	**32711,58**		60535,77
Die Angaben in der Spalte 6 "Summe 2022" enthalten die von den Wirtschaftsprüfern gemäß § 7 Absatz 1 a AtG geprüften Werte.							
Das Kernkraftwerk Emsland hat vor Ablauf des 31. Dezember 2022 seine verbleibende Elektrizitätsmenge verbraucht. Der Leistungsbetrieb kann nach § 7 Absatz 1e AtG unabhängig von den in Anlage 3 Spalte 2 genannten oder nach Übertragung verbleibender Elektrizitätsmengen bis längstens zum Ablauf des 15. April 2023 erfolgen. (Spalte 8)							

[1] Übertragung der verbliebenen Elektrizitätsmenge des Kernkraftwerkes Stade von 4785,53 GWh am 11. Mai 2010 auf das Kernkraftwerk Biblis A (Spalte 7).
[2] Übertragung von insgesamt 5499,89 GWh vom Kernkraftwerk Philippsburg 1 auf das Kernkraftwerk Obrigheim am 23. Januar 2003 und 11.Mai 2005 (Spalte 7).
[3] Übertragung von 8100,00 GWh der verbliebenen Elektrizitätsmenge des stillgelegten Kernkraftwerkes Mülheim-Kärlich auf das Kernkraftwerk Biblis B am 30. Juni 2010 (Spalte 7).
[4] Übertragung von 8400,00 GWh auf das Kernkraftwerk Gundremmingen B sowie 1500,00 GWh auf das Kernkraftwerk Gundremmingen C aus dem verbliebenen Elektrizitätsmengenkontingent des stillgelegten Kernkraftwerkes Mülheim-Kärlich am 28. Mai 2015 (Spalte 7).
[5] Übertragung von 2800,00 GWh auf das Kernkraftwerk Gundremmingen B und 500,00 GWh auf das Kernkraftwerk Gundremmingen C aus dem verbliebenen Elektrizitätsmengenkontingent des abgeschalteten Kernkraftwerkes Unterweser am 28. Mai 2015 (Spalte 7).
[6] Übertragung von 500,00 GWh auf das Kernkraftwerk Grafenrheinfeld vom Elektrizitätsmengenkontingent des abgeschalteten Kernkraftwerks Unterweser am 5. Juni 2015 (Spalte 7).
[7] Übertragung von 8000,00 GWh auf Gundremmingen B: von Biblis B (6000,00 GWh) und von Unterweser (2000,00 GWh) am 27. Januar 2017 (Spalte 7).
[8] Übertragung von 8000,00 GWh auf Gundremmingen C: von Biblis A (2194,24 GWh), von Biblis B (1822,48 GWh), von Mülheim-Kärlich (1983,28 GWh) und von Unterweser (2000,00 GWh) am 27. Januar 2017 (Spalte 7).
[9] Übertragung von 31000,00 GWh auf Gundremmingen C: von Mülheim-Kärlich (30000,00 GWh) und von Unterweser (1000,00 GWh) am 10. Januar 2018 (Spalte 7).
[10] Übertragung der verbliebenen Elektrizitätsmenge des Kernkraftwerkes Philippsburg 1 von 8454,24 GWh auf das Kernkraftwerk Philippsburg 2 am 20. März 2018 (Spalte 7).
[11] Übertragung von 17700,00 GWh auf das Kernkraftwerk Emsland aus dem verbliebenen Elektrizitätsmengenkontingent des stillgelegten Kernkraftwerkes Mülheim-Kärlich am 15. Oktober 2018 (Spalte 7).
[12] Mit Wirkung vom 15. Januar 2019 wurden 4673,79 GWh auf das Kernkraftwerk Grohnde von den Anlagen Unterweser (2402,86 GWh), Grafenrheinfeld (246,81 GWh) und Isar 1 (2024,12 GWh) übertragen (Spalte 7).
[13] Mit Wirkung vom 11. Juli 2019 wurden 10000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Grohnde übertragen (Spalte 7).
[14] Mit Wirkung vom 18. November 2019 wurden 5122,00 GWh aus dem Elektrizitätsmengenkontingent des stillgelegten Kernkraftwerkes Mülheim-Kärlich auf das Kernkraftwerk Isar 2 übertragen (Spalte 7).
[15] Mit Wirkung vom 5. Februar 2020 wurden 6000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Isar 2 übertragen (Spalte 7).
[16] Mit Wirkung vom 21. Februar 2020 wurden 5000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Brokdorf übertragen (Spalte 7).
[17] Mit Wirkung vom 7. Oktober 2020 wurden 3000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Grohnde übertragen (Spalte 7).
[18] Mit Wirkung vom 3. Dezember 2020 wurden 1047,47 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Gundremmingen Block B auf das Kernkraftwerk Gundremmingen Block C übertragen (Spalte 7).
[19] Mit Wirkung vom 17. Dezember 2020 wurden 5000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Brokdorf übertragen (Spalte 7).
[20] Mit Wirkung vom 6. Januar 2021 wurden 5000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Grohnde übertragen (Spalte 7).
[21] Mit Wirkung vom 6. Januar 2021 wurden 5000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Isar 2 übertragen (Spalte 7).
[22] Mit Wirkung vom 26. März 2021 wurden 5000,00 GWh aus dem Elektrizitätsmengenkontingent des stillgelegten Kernkraftwerks Mülheim-Kärlich auf das Kernkraftwerk Gundremmingen Block C übertragen (Spalte 7).
[23] Mit Wirkung vom 12. Mai 2021 wurden 5500,00 GWh auf das Kernkraftwerk Brokdorf von den Kernkraftwerken Krümmel (1833,443 GWh) und Brunsbüttel (3666,557 GWh) übertragen (Spalte 7).
[24] Mit Wirkung vom 15. Juli 2021 wurden 4604,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Grohnde übertragen (Spalte 7).
[25] Mit Wirkung vom 29. Juli 2021 wurden 4000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Isar 2 übertragen (Spalte 7).
[26] Mit Wirkung vom 4. Oktober 2021 wurden 1900,00 GWh aus dem Elektrizitätsmengenkontingent des stillgelegten Kernkraftwerks Mülheim-Kärlich auf das Kernkraftwerk Gundremmingen Block C übertragen (Spalte 7).
[27] Mit Wirkung vom 12. November 2021 wurden 500,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Brokdorf übertragen (Spalte 7).
[28] Mit Wirkung vom 26. November 2021 wurden 145,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Philippsburg 2 auf das Kernkraftwerk Brokdorf übertragen (Spalte 7).
[29] Mit Wirkung vom 26. November 2021 wurden 2000,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Neckarwestheim 2 übertragen (Spalte 7).
[30] Mit Wirkung vom 3. Dezember 2021 wurden 10285,112 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Krümmel auf das Kernkraftwerk Isar 2 übertragen (Spalte 7).
[31] Mit Wirkung vom 28. Februar 2022 wurden 1946,15 GWh auf das Kernkraftwerk Emsland von den Kernkraftwerken Gundremmingen Block C (301,43 GWh) und Mülheim-Kärlich (1644,72 GWh) übertragen (Spalte 7).
[32] Mit Wirkung vom 23. September 2022 wurden von dem stillgelegten Kernkraftwerk Philippsburg 2 Elektrizitätsmengen in Höhe von 1467,38 GWh auf das Kernkraftwerk Neckarwestheim 2 und in Höhe von 60 GWh auf das Kernkraftwerk Emsland übertragen (Spalte 7).
[33] Übertragung von 296,00 GWh auf das Kernkraftwerk Isar 2: von den endgültig abgeschalteten Kernkraftwerken Brokdorf (194,00 GWh) am 8. Dezember 2022 und Grohnde (102,00 GWh) am 9. Dezember 2022 (Spalte 7).
[34] Übertragung von 410,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Isar 2 auf das Kernkraftwerk Neckarwestheim 2 am 9. Dezember 2022 (Spalte 7).
[35] Übertragung von 2,308 GWh aus dem Elektrizitätsmengenkontingent des endgültig abgeschalteten Kernkraftwerks Brokdorf auf das Kernkraftwerk Neckarwestheim 2 am 16. Dezember 2022 (Spalte 7).
[36] Übertragung von 100,00 GWh aus dem Elektrizitätsmengenkontingent des Kernkraftwerks Isar 2 auf das Kernkraftwerk Neckarwestheim 2 am 21. Dezember 2022 (Spalte 7).

Table I.3: Nuclear power plants in operation, as of 31 December 2022

No.	Name	Abbreviation	Reactor type	Output MW_e	First criticality date	In power operation	Operator	Location
1	Neckarwestheim 2[1]	GKN 2	PWR	1,400	29 December 1988	1989	EnBW Kernkraft GmbH (EnKK)	Neckarwestheim (BW)
2	Isar 2[2]	KKI 2	PWR	1,485	15 January 1988	1988	PreussenElektra GmbH	Essenbach (BY)
3	Emsland[3]	KKE	PWR	1,406	14 April 1988	1988	Nuclear Power Plant Lippe-Ems GmbH	Lingen (NI)

[1] After the editorial deadline: The decommissioning and dismantling licence for GKN 2 was granted on 4 April 2023

[2] Application in accordance with Section 7 (3) of the Atomic Energy Act for decommissioning and dismantling the plant (1st SAG) dated 1 July 2019

[3] Application pursuant to Section 7 (3) of the Atomic Energy Act for decommissioning and dismantling dated 22 December 2016

Table I.4: Nuclear power plants finally shut down, as of 31 December 2022

No.	Name	Abbreviation	Reactor type	Output MW_e (gross)	First criticality date	In power operation	Shut down	Application for decommissioning	Operator	Location
1	Krümmel	KKK	BWR	1,402	14 September 1983	1984	6 August 2011	24 August 2015	Krümmel Nuclear Power Plant GmbH & Co. oHG	Krümmel (SH)
2	Grohnde	KWG	PWR	1,430	1 September 1984	1985	31 December 2021	26 October 2017	PreussenElektra GmbH	Emmerthal (NI)
3	Brokdorf	KBR	PWR	1,480	8 October 1986	1986	31 December 2021	1 December 2017	PreussenElektra GmbH	Brokdorf (SH)

Table I.5: Nuclear power plants in decommissioning

No.	Name	Abbreviation	Reactor type	Output MW_e (gross)	First criticality date	In power operation	Taken out of service	First decommissioning licence	Operator	Location
1	Rheinsberg (ö.H.)	KKR	PWR / WWER	70	11 March 1966	1966	1 June 1990	28 April 1995	Nuclear Waste Management Plant GmbH (EWN)	Rheinsberg (BB)
2	Compact sodium-cooled nuclear plant (ö.H.)	KNK II	SNR	21	10 October 1977	1979	23 August 1991	26 August 1993	Kerntechnische Entsorgung Karlsruhe GmbH (company of the EWN)	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 September 1965	1966	3 May 1984	17 November 1987	Kerntechnische Entsorgung Karlsruhe GmbH (company of the EWN)	Eggenstein-Leopoldshafen (BW)
4	Obrigheim	KWO	PWR	357	22 September 1968	1969	11 May 2005	28 August 2008	EnBW Kernkraft GmbH (EnKK)	Obrigheim (BW)
5	Neckarwestheim 1	GKN 1	PWR	840	26 May 1976	1976	6 August 2011	3 February 2017	EnBW Kernkraft GmbH (EnKK)	Neckarwestheim (BW)
6	Philippsburg-1	PPP 1	BWR	926	9 March 1979	1980	6 August 2011	7 April 2017	EnBW Kernkraft GmbH (EnKK)	Philippsburg (BW)
7	Philippsburg 2	PPP 2	PWR	1,468	13 December 1984	1985	31 December 2019	17 December 2019	EnBW Kernkraft GmbH (EnKK)	Philippsburg (BW)
8	Isar 1	KKI 1	BWR	912	20 November 1977	1979	6 August 2011	17 January 2017	PreussenElektra GmbH	Essenbach (BY)

No.	Name	Abbreviation	Reactor type	Output MW_e (gross)	First criticality date	In power operation	Taken out of service	First decommissioning licence	Operator	Location
9	Gundremmingen A	KRB A	BWR	250	14 August 1966	1967	13 January 1977	26 May 1983	RWE Nuclear GmbH	Gundremmingen (BY)
10	Grafenrheinfeld	KKG	PWR	1,345	9 December 1981	1982	27 June 2015	11 April 2018	PreussenElektra GmbH	Grafenrheinfeld (BY)
11	Gundremmingen B	KRB II B	BWR	1,344	9 March 1984	1984	31 December 2017	19 March 2019	RWE Nuclear GmbH	Gundremmingen (BY)
12	Biblis-A	KWB A	PWR	1,225	16 July 1974	1975	6 August 2011	30 March 2017	RWE Nuclear GmbH	Biblis (HE)
13	Biblis-B	KWB B	PWR	1,300	25 March 1976	1977	6 August 2011	30 March 2017	RWE Nuclear GmbH	Biblis (HE)
14	Greifswald-1 (ö.H.) In the case of units KGR 1 to 5, it should also be mentioned that unit 6 was well advanced in its construction but did not become critical. However, unit 6 belongs to the nuclear facility and thus to the dismantling volume of EWN GmbH.	KGR 1	PWR / WWER	440	3 December 1973	1974	18 December 1990	30 June 1995	Nuclear Waste Management Plant GmbH (EWN)	Lubmin (MV)
15	Greifswald-2 (ö.H.)	KGR 2	PWR / WWER	440	3 December 1974	1975	14 February 1990	30 June 1995	Nuclear Waste Management Plant GmbH (EWN)	Lubmin (MV)
16	Greifswald-3 (ö.H.)	KGR 3	PWR / WWER	440	6 October 1977	1978	28 February 1990	30 June 1995	Nuclear Waste Management Plant GmbH (EWN)	Lubmin (MV)

No.	Name	Abbreviation	Reactor type	Output MW_e (gross)	First criticality date	In power operation	Taken out of service	First decommissioning licence	Operator	Location
17	Greifswald-4 (ö.H.)	KGR 4	PWR / WWER	440	22 July 1979	1979	2 June 1990	30 June 1995	Nuclear Waste Management Plant GmbH (EWN)	Lubmin (MV)
18	Greifswald-5 (ö.H.)	KGR 5	PWR / WWER	440	26 March 1989	-	30 November 1989	30 June 1995	Nuclear Waste Management Plant GmbH (EWN)	Lubmin (MV)
19	Lingen 268 MWe was the electrical output at the generator incl. additional fossil component; electrical output from nuclear power generation 252 MWe.	KWL	BWR	252	31 January 1968	1968	5 January 1977	21 November 1985 30 March 1988 SE 21 December 2015 (Dismantling of the plant)	Nuclear power plant Lingen GmbH	Lingen (NI)
20	Stade	KKS	PWR	672	8 January 1972	1972	14 November 2003	7 September 2005	PreussenElektra GmbH	Stade (NI)
21	Lower Weser	MSE	PWR	1,410	16 September 1978	1979	6 August 2011	5 February 2018	PreussenElektra GmbH	Esenshamm (NI)
22	Jülich Experimental Reactor Working Group (ö.H.)	AVR	HTR	15	26 August 1966	1969	31 December 1988	9 March 1994	JEN mbH (company of EWN-GmbH), formerly AVR GmbH	Jülich (NRW)
23	Thorium high-temperature reactor (ö.H.)	THTR-300	HTR	308	13 September 1983	1987	29 September 1988	22 October 1993, 05/1997 SE	HKG	Hamm-Uentrop (NRW)

No.	Name	Abbreviation	Reactor type	Output MW_e (gross)	First criticality date	In power operation	Taken out of service	First decommissioning licence	Operator	Location
24	Würgassen	KWW	BWR	670	22 October 1971	1975	26 August 1994 Closure decision of the operator on 29 May 95	14 April 1997	PreussenElektra GmbH	Würgassen (NRW)
25	Mülheim-Kärlich	KMK	PWR	1,302	1 March 1986	1987	9 September 1988	16 July 2004	RWE Nuclear GmbH	Mülheim-Kärlich (RP)
26	Brunsbüttel	KKB	BWR	806	3 December 1973	1977	6 August 2011	21 December 2018	Brunsbüttel Nuclear Power Plant GmbH & Co. oHG	Brunsbüttel (SH)
27	Gundremmingen C	KRB II C	BWR	1,344	26 October 1984	1985	31 December 2021	19 March 2019	RWE Nuclear GmbH	Gundremmingen (BY)

(ö.H.) Funded by the public sector

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Table I.6: Nuclear power plants released from the AtG

No.	Name	Abbbreviation	Reactor type	Output MW_e (gross)	First criticality date	In power operation	Shut-down date	First Decommissioning licence | Decommissioning ended	Operator	Location
1	Grosswelzheim hot steam reactor (ö.H.)	HDR	HDR (Hot Steam Reactor)	25	14 October 1969	1970 (trial operation only)	20 April 1971	16 February 1983/ Released from AtG: 14 May 1998 Dismantled: 15 October 1998	Karlsruhe Research Centre GmbH	Karlstein (BY)
2	Niederaichbach (ö.H.) heavy-water-moderated pressure-tube reactor with CO_2 gas cooling	KKN	DRR / D_2O-Moderator	106	17 December 1972	1973 (trial operation only)	31 July 1974	21 October 1975/ Released from AtG: 17 August 1994 Dismantled: 17 August 1995	Karlsruhe Research Centre GmbH	Niederaichbach (BY)
3	Kahl experimental nuclear power plant	VAK	BWR	16	13 November 1960	1962	25 November 1985	5 May 1988/ Released from AtG: 17 May 2010 Dismantled: 24 September 2010	VAK	Karlstein (BY)

Table I.7: Discontinued nuclear power plant projects

No.	Name	Abbreviation	Operator	Type	Gross output [MW]$_e$	Comments
1	Greifswald-6	KGR 6	Energiewerke Nord GmbH	PWR	440	Final shutdown: 30 November 1989 General decommissioning/dismantling of the complete facility: 30 June 1995 ff.
2	Greifswald-7	KGR 7	Energiewerke Nord GmbH	PWR	440	Project discontinued
3	Greifswald-8	KGR 8	Energiewerke Nord GmbH	PWR	440	Project discontinued
4	Kalkar fast sodium-cooled reactor	SNR 300	Schnell-Brüter-Kernkraftwerksgesellschaft mbH	SNR	327	Project discontinued 20 March 1991
5	Stendal nuclear power plant Block A	Stendal A	Altmark Industrie GmbH	PWR	1,000	Project discontinued
6	Stendal nuclear power plant Block B	Stendal B	Altmark Industrie GmbH	PWR	1,000	Project discontinued

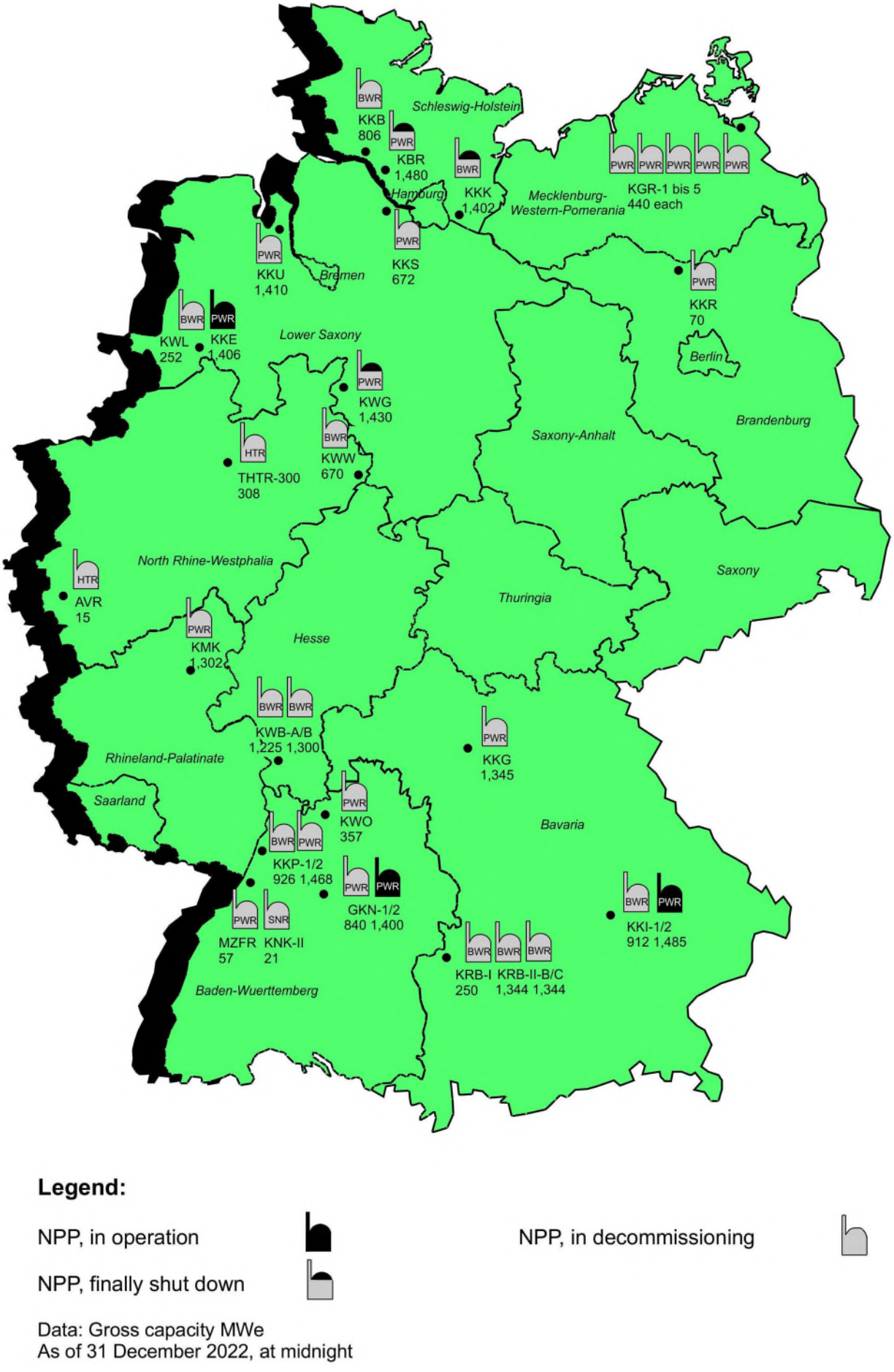

Fig. I.1: Nuclear power plants in the Federal Republic of Germany (in German only)

1957	**First research reactors in Germany** In 1957, the two research reactors in West and East go into operation: the Munich research reactor, the so-called Garching Atomic Egg, and the Rossendorf research reactor. These two facilities are used for research purposes and not for generating electricity.
1960	**Atomic Energy Act in the Federal Republic of Germany** The Atomic Energy Act comes into force in the Federal Republic of Germany. Its purpose ist he peaceful utilization of nuclear energy and protection against its dangers. The issue of waste disposal is not addressed.
1960	**Kahl Experimental Nuclear Power Plant** The Kahl Experimental Nuclear Power Plant is commissioned in 1960 with an electrical output of 16 MW. It is the first commercial nuclear power plant in the Federal Republic of Germany. A total of 36 nuclear power plants will go into operation in the FRG.
1962	**Atomic Energy Act in the GDR** The law on the use of nuclear energy in the GDR (Atomic Energy Act) is passed by the Peoples`s Chamber of the GDR.
1966	**Rheinsberg Nuclear Power Plant** The GDR`s first commercial nuclear power plant in Rheinsberg is commissioned in 1966 with an electrical output of 70 MW.
1973	**Greifswald Nuclear Power Plant** The first unit of the Greifswald nuclear power plant goes into operation in the GDR. A total of 8 units oft he Russian WWER-440 type were planned, each with an electrical output of 440 MW. Units 2-4 were commissioned in 1974, 1977 and 1979.
1975	**Biblis Nuclear Power Plant** In 1975, the first oft wo units oft he twin-unit Biblis nuclear power plant, Biblis Unit A, goes into operation. With an electrical output of around 1200 MW, Biblis A is considered the largest reactor Unit in the world at the time. Biblis Unit B also goes into operation in 1977.
1982	**Stendal Nuclear Power Plant** A construction licence for two units of a pressurised water reactor oft he Russian type WWER-1000, each with an electrical output of 1000 MW, is granted for the Stendal site. Construction work is stopped during the reunification period 1990.
1985	**Fast Breeder Reactor Kalkar** The fast breeder reactor in Kalkar ist completed in 1985, but does not go into operation. The project is cancelled in 1991. The site is used as an amusement parc from 1996.
1988	**Isar 2, Emsland und Neckarwestheim 2 Nuclear Power Plants** The Isar Unit 2, Emsland and Neckarwestheim Unit 2 nuclear power plants, the three newest plants in Germany to date, go into operation. They are pressurised water reactors with electrical outputs of around 1400 MW and more.
1989/ 1990	**Greifswald und Rheinsberg Nuclear Power Plants** In the GDR, unit 5 at the Greifswald nuclear power plant reaches first criticality in 1989, but does not go into operation. Units 1-4 are taken out of operation. Construction work on units 6 to 8 is stopped in 1990. The Rheinsberg nuclear power plant ist also finally shut down in 1990.
1990	**Atomic Energy Act in reunified Germany** With the entry into force of the Treaty on the Creation on the Monetary, Economic and Social Union between the Federal Republic of Germany and the GDR, the Atomic Energy Act also becomes applicable in the new federal states from July 1990.
2002	**First Nuclear Phase-out** The Bundestag introduces the Nuclear Phase-out Act („Act on the Orderly Termination of Nuclear Energy Utilisation for the Commercial Generation of Electricity"). Once the remaining electricity volumes have been produced, the licences to operate nuclear power plants will expire.
2010	**Lifetime Extension** With the lifetime extension, the federal legislator introduces additional residual electricity volumes for the individual nuclear power plants.
2011	**Second Nuclear phase-out** An earthquake followed by a tsunami leads to a nuclear disaster at the Fukushima Daiichi nuclear power plant on 11 March 2011. As a result the Bundestag passes a cross-party solution to finally phase out the use of nuclear energy. The nuclear power plants Biblis Unit A and B, Neckarwestheim Unit 1, Brunsbüttel, Isar Unit 1, Unterweser, Philippsburg Unit 1 and Krümmel lose their operating licences.
2015	**Grafenrheinfeld Nuclear Power Plant** The operator finally shuts down Grafenrheinfeld nuclear power plant on 27 June 2015, six months before its operating licence expires at the end of the year.
2017	**Gundremmingen Nuclear Power Plant Unit B** The Gundremmingen nuclear power plant unit B loses its licence for power operation on 31.12.2017.
2019	**Philippsburg Nuclear Power Plant Unit 2** The Philippsburg nuclear power plant unit 2 loses its licence for power operation on 31.12.2019.
2021	**Grohnde, Gundremmingen Unit C und Brokdorf Nuclear Power Plants** Grohnde, Gundremmingen Unit C and Brokdorf nuclear power plants lose their licence for power operation on 31.12.2021.
2022	**Isar Unit 2, Emsland und Neckarwestheim Unit 2 Nuclear Power Plants** According to the 19th amendment to the Atomic Energy Act of 4 December 2022, the final shutdown of the last three nuclear power plants operated in Germany, Isar Unit 2, Emsland and Neckarwestheim Unit 2, will be postponed from 31 December 2022 to 15 April 2023.

Fig. I.2: Development of the use of nuclear energy in Germany over time

Annex II - Research reactors

Correct on 31 December 2022

Table II. 1: Research reactors in operation

No.	Name	Abbreviation	Type / reactor type; output	First criticality date	Operator	Location
1	SUR Furtwangen	SUR-FW	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	28 June 1973	Furtwangen University Laboratory for Radiation Measurement	Furtwangen (BW)
2	SUR Stuttgart 1969: Conversion and move to another building	SUR-S	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	24 August 1964 / 12 June 1969	University of Stuttgart, Institute for Nuclear Energy and Energy Systems	Stuttgart (BW)
3	SUR Ulm	SUR-U	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	1 December 1965	Ulm University of Applied Sciences, Institute for Radiation Measurement	Ulm (BW)
4	High Flux Neutron Source Munich/Garching	FRM-II	Pool-type / compact core with D_2O moderator; 20 MW_{th}	2 March 2004	Technical University of Munich	Garching (BY)
5	Mainz research reactor	FRMZ	Pool-type / TRIGA MARK-II; 0.1 MW_{th}	3 August 1965	Gutenberg University Mainz, Department of Chemistry	Mainz (RP)
6	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	Homogeneous (S) / SUR type; 2.0E-06 MW_{th}	28 July 1978 / 22 March 2005	Technical University of Dresden, Institute of Power Engineering	Dresden (SN)

Table II. 2: Research reactors finally shut down

No.	Name	Abbreviation	Type/reactor type; Output	First criticality date	Taken out of service	Request for Decommissioning	Operator	Location
1	Berlin Experimental Reactor II	BER II	Pool-type / MTR; 10 MW_{th}	9 December 1973	11 December 2019	24 April 2017	Helmholtz Centre Berlin for Materials and Energy GmbH, formerly Hahn-Meitner-Institut	Berlin (BE)
2	Research reactor Geesthacht-1	FRG-1	Pool-type / MTR; 5 MW_{th}	23 October 1958	28 June 2010	21 March 2013[1]	Helmholtz Centre Geesthacht Centre for Materials and Coastal Research GmbH	Geesthacht (SH)
3	Research reactor Geesthacht-2	FRG-2	Pool-type / MTR; 15 MW_{th}	16 March 1963	28 January 1993 Application for decommissioning 17 January 1995 General decommissioning and partial dismantling	21 March 2013 Application to dismantle the research reactor (consisting of FRG-1 and still existing unit parts of FRG2-)	Helmholtz Centre Geesthacht Centre for Materials and Coastal Research GmbH	Geesthacht (SH)

[1] The application to decommission and dismantle FRG-1 and dismantle the research reactor unit and the hot laboratory were further specified 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) is to be included in the procedure.

Table II. 3: Research reactors being decommissioned

No.	Name	Abbreviation	Type /reactor type; output	First criticality date	Taken out of service	First decommissioning licence	Operator	Location
1	Research reactor-2	FR-2	Tank / D_2O; 44 MW_{th}	7 March 1961	21 December 1981	3 July 1986 | 20 November 1996 SE	Kerntechnische Entsorgung Karlsruhe GmbH (company of EWN GmbH)	Eggenstein-Leopoldshafen (BW)
2	Research reactor Munich	FRM	Pool-type / MTR; 4 MW_{th}	31 October 1957	28 July 2000	3 April 2014	Munich University of Technology	Garching (BY)
3	Neuherberg research reactor	FRN	Pool-type / TRIGA MARK-III; 1 MW_{th}	23 August 1972	16 December 1982	30 May 1983 | 24 May 1984 SE	Helmholtz Zentrum München - German Research Center for Environmental Health (GmbH)	Oberschleißheim (BY)
4	Braunschweig research and measurement reactor	FMRB	Pool-type / MTR; 1 MW_{th}	3 October 1967	19 December 1995	2 March 2001 I 28 July 2005 (Unit released from the Atomic Energy Act with the exception of the interim storage facility)	Physikalisch-Technische Bundesanstalt	Brunswick (NI)
5	DIDO	FRJ-2	Tank / D_2O; 23 MW_{th}	14 November 1962	2 May 2006	20 September 2012	JEN mbH (company of EWN-GmbH), formerly Forschungszentrum Jülich GmbH	Jülich (NRW)
6	Siemens Teaching Reactor Aachen	SUR-AA	homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	22 September 1965	2002 (Unit has been nuclear fuel-free since 2008)	26 June 2020	RWTH Aachen University, Institute for Electrical Systems and Energy Economics	Aachen (NRW)

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Table II. 4: Research reactors released from the AtG

No.	Name	Abbreviation	Type /reactor type; output	First criticality date	Taken out of service	First decommissioning licence | Decommissioning ended	Operator	Location
1	Fast zero-power assembly	SNEAK	Homogeneous (S); 1.0E-03 MW_{th}	15 December 1966	11/1985	3 June 1986 6 May 1987	Nuclear Research Centre Karlsruhe GmbH	Eggenstein-Leopoldshafen (BW)
2	Fast subcritical assembly Licence according to Section 9 AtG	SUAK	Fast subcritical assembly; 0 MW_{th}	20 November 1964 Commissioning	7 December 1978		Nuclear Research Centre Karlsruhe GmbH	Eggenstein-Leopoldshafen (BW)
3	Fast thermal Argonaut autoreactor	STARK	Argonaut; 1.0E-05 MW_{th} Modified fast-thermal Argonaut reactor	11 January 1963	03/1976	1976 | 1977	Nuclear Research Centre Karlsruhe GmbH	Eggenstein-Leopoldshafen (BW)
4	Siemens Training Reactor Karlsruhe	SUR-KA	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	7 March 1966	09/1996	25 November 1996 26 June 1998 Reactor is exhibited without nuclear fuel at the Mannheim Museum of Technology.	Research Centre Karlsruhe GmbH	Eggenstein-Leopoldshafen (BW)
5	TRIGA Heidelberg I	TRIGA HD I	Pool-type /TRIGA MARK-I; 0.25 MW_{th}	26 August 1966	31 March 1977	30 June 1980 11 December 1980 (SE) 16 January 2006 (AG) 13 December 2006 Unit demolished and 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 February 1978	30 November 1999	13 September 2004 13 December 2006	German Cancer Research Centre	Heidelberg (BW)

No.	Name	Abbreviation	Type /reactor type; output	First criticality date	Taken out of service	First decommissioning licence | Decommissioning ended	Operator	Location
7	AEG zero-power reactor, thermal-critical assembly	TKA	Tank / thermally critical assembly; 1.0E-04 MW_{th}	23 June 1967	1973	28 September 1981 21 December 1981	Power Station Union AG	Karlstein (BY)
8	AEG test reactor	PR-10	Argonaut; 1.80E-04 MW_{th}	27 January 1961	1976	27 July 1976 22 February 1978	Power Station Union AG	Karlstein (BY)
9	Siemens Argonaut Reactor	SAR	Argonaut; 1.0E-03 MW_{th}	23 June 1959	31 October 1968	8 January 1992 (AG) 20 March 1998	Technical University Munich	Garching (BY)
10	Siemens Subcritical Assembly SUA was a part of the SUR-Munich	SUA	Subcritical assembly; 0 MW_{th}	06/1959 Commissioning	1968	31 October 1968 28 August 1992 (AG) 20 March 1998	Technical University Munich	Garching (BY)
11	Siemens Training Reactor Munich	SUR-M	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	28 February 1962	10 August 1981	28 August 1992 (AG) 20 March 1998	Technical University Munich	Garching (BY)
12	Berlin Experimental Reactor	BER I	Homogeneous (L) / L54-(L); 0.05 MW_{th}	24 July 1958	Summer 1972	15 February 1974 (Revocation of the operating licence) 23 April 1974	Hahn Meitner Institute (today: Helmholtz Centre Berlin for Materials and Energy)	Berlin (BE)
13	Siemens Training Reactor Berlin	SUR-B	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	26 July 1963	15 October 2007	1 December 2008 16 April 2013	Berlin University of Technology, Institute of Energy Technology, Department of Nuclear Technology	Berlin (BE)
14	Siemens Training Reactor Bremen	SUR-HB	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	10 October 1967	17 June 1993	5 June 1997 27 July 1999 (AG) 03/2000	Bremen University	Bremen (HB)

No.	Name	Abbreviation	Type /reactor type; output	First criticality date	Taken out of service	First decommissioning licence | Decommissioning ended	Operator	Location
15	Siemens Training Reactor Hamburg	SUR-HH	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	15 January 1965	08/1992	31 March 1999 12/1999	Hamburg University of Applied Sciences	Hamburg (HH)
16	Research reactor Frankfurt -1	FRF 1	Homogeneous (L) / L-54(L); 0.05 MW_{th}	10 January 1958	19 March 1968	1970 31 October 2006	Johann Wolfgang Goethe University	Frankfurt (HE)
17	Research reactor Frankfurt -2	FRF-2	Pool-type / modified TRIGA; 1 MW_{th}	No criticality	No operation	25 October 1982 31 October 2006	Johann Wolfgang Goethe University	Frankfurt (HE)
18	Siemens Training Reactor Darmstadt	SUR-DA	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	23 September 1963	22 February 1985	23 November 1989 2 August 1990 (AG) 29 November 1996	Darmstadt University of Technology	Darmstadt (HE)
19	TRIGA-Hanover	FRH/TRIGA MHH	Pool-type /TRIGA Mark-I; 0.25 MW_{th}	31 January 1973	18 December 1996	8 May 2006 13 March 2008	Hanover Medical School	Hanover (NI)
20	Siemens Training Reactor Hanover	SUR-H	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	9 December 1971	Unit had been nuclear fuel-free since 2008	4 September 2017 18 September 2019	Leibniz Universität Hannover Institute of Nuclear Technology and Non-destructive Testing	Hanover (NI)
21	MERLIN research reactor	FRJ-1	Pool-type / MTR; 10 MW_{th}	24 February 1962	22 March 1985	8 June 1995 23 November 2007	Research Centre Jülich GmbH	Jülich (NRW)
22	Burn-up measurement of differential fuel rods with critical assembly	ADIBKA	Homogeneous (L) / L77A; 1.0E-04 MW_{th}	18 March 1967	30 October 1972	7 July 1977 12/1977	High-Temperature Reactor Construction GmbH	Jülich (NRW)

No.	Name	Abbreviation	Type /reactor type; output	First criticality date	Taken out of service	First decommissioning licence | Decommissioning ended	Operator	Location
23	Critical assembly for high-temperature reactors	KAHTER	Critical assembly; 1.0E-04 MW_{th}	2 July 1973	3 February 1984	9 November 1987 06/1988	Nuclear Research Facility Jülich	Jülich (NRW)
24	Critical experiment for in-core thermionic reactor	KEITER	Critical assembly; 1.0E-06 MW_{th}	15 June 1971	1982	18 March 1982 06/1988	Nuclear Research Facility Jülich	Jülich (NRW)
25	Rossendorf assembly for critical experiments	RAKE	Tank / critical assembly; 1.0E-05 MW_{th}	3 October 1969	26 November 1991	19 August 1997 28 October 1998	VKTA Radiation Protection, Analysis and Disposal Rossendorf e.V.	Rossendorf (SN)
26	Rossendorf ring zone reactor	RRR	Argonaut; 1.0E-03 MW_{th}	16 December 1962	25 September 1991	31 March 1999 11 May 2000	VKTA Radiation Protection, Analysis and Disposal Rossendorf e.V.	Rossendorf (SN)
27	Zittau Teaching and Research Reactor Licence pursuant to Section 57a AtG limited until 30 June 2005	ZLFR	Tank / WWR-M; 1.0E-05 MW_{th}	25 May 1979	24 March 2005 Last operation	1 July 2005 3 May 2006	Zittau/Görlitz University of Applied Sciences (FH) Department of Mechanical Engineering	Zittau (SN)
28	Rossendorf research reactor	RFR	Tank / WWR-SM; 10 MW_{th}	16 December 1957	27 June 1991	30 January 1998 19 September 2019	VKTA Radiation Protection, Analysis and Disposal Rossendorf e.V.	Rossendorf (SN)
29	Facility for zero-power experiments	ANEX	Critical assembly; 1.0E-04 MW_{th}	05/1964	5 February 1975	19 March 1979 (AG) 01/1980	GKSS Research Centre Geesthacht GmbH	Geesthacht (SH)

No.	Name	Abbreviation	Type /reactor type; output	First criticality date	Taken out of service	First decommissioning licence | Decommissioning ended	Operator	Location
30	"Otto Hahn“ nuclear vessel Responsible supervisory body in Hamburg under the Atomic Energy Act	OH	PWR / marine reactor; 38 MW_{th} assigned to the FR in Germany	26 August 1968	22 March 1979	1 December 1980 1 September 1982	GKSS Research Centre Geesthacht GmbH	Geesthacht (SH)
31	Siemens Training Reactor Kiel	SUR-KI	Homogeneous (S) / SUR-100; 1.0E-07 MW_{th}	29 March 1966	11 December 1997	19 March 2008 2 April 2008	Kiel University of Applied Sciences	Kiel (SH)

AG Dismantling licence
SE Safe enclosure

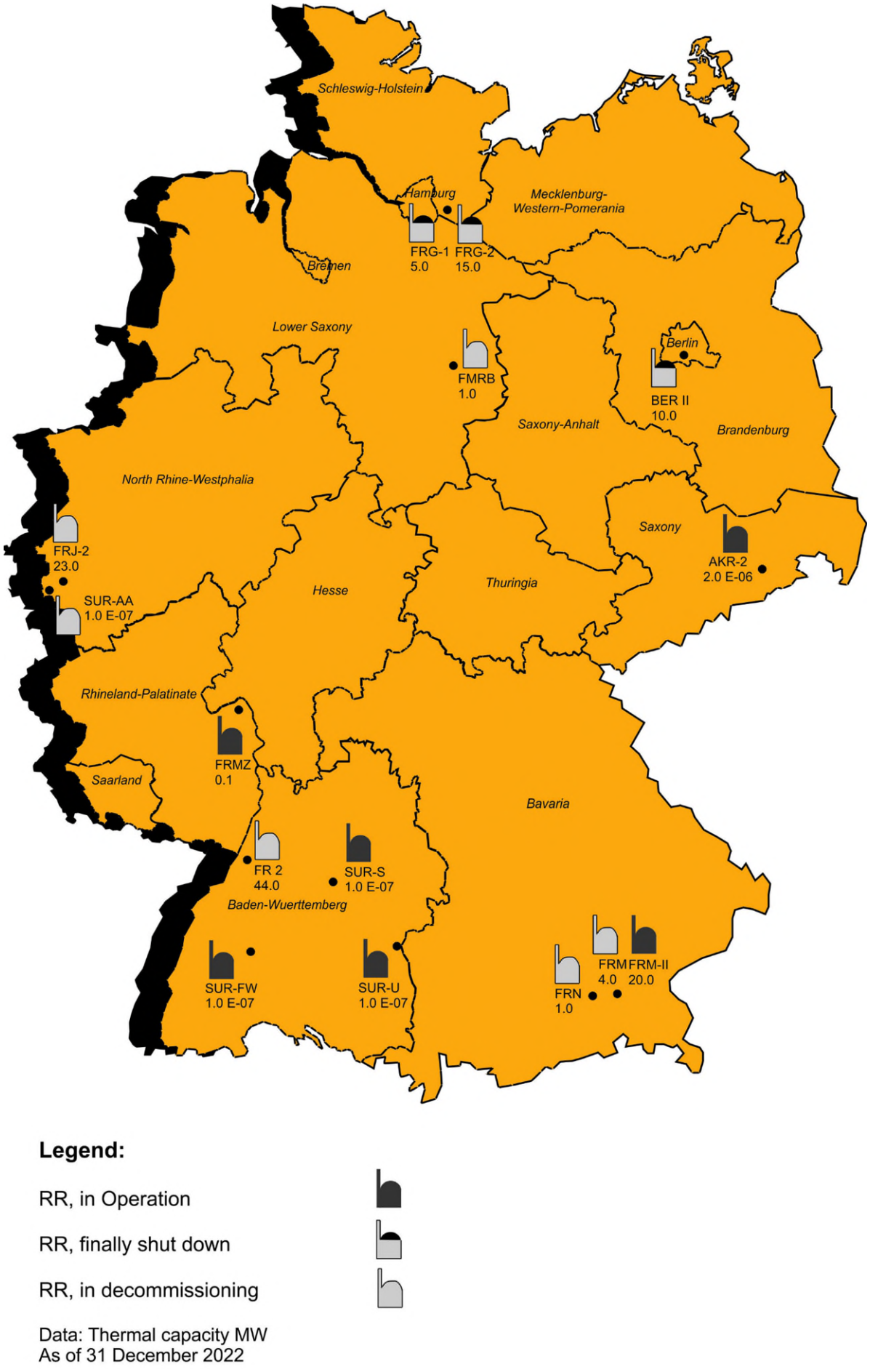


Fig. II.1: Research reactors in the Federal Republic of Germany

Annex III - Facilities for nuclear supply and waste management

Correct on 31 December 2022

Table III. 1: Uranium enrichment plants

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Gronau Uranium Enrichment Plant (UAG) Gronau (NW)	Uranium enrichment	4,500 Mg uranium separation work per year (UTA/a) according to the decision of 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 has not yet been commissioned.

TG partial licence

Table III. 2: Fuel element factories in operation

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	ANF Fuel Assembly Fabrication Plant Lingen Lingen (NI)	Production of predominantly LWR fuel elements from low-enriched uranium dioxide	Treatment and processing of a total of 800 Mg uranium per year in the form of uranium powder or uranium pellets with up to 5 % U-235 (dry conversion), 650 Mg uranium/a for individual plant units	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 externally manufactured uranium tablets per annum; 11 Jan. 2005: increase of the uranium powder throughput to 650 Mg/a 2 Dec. 2009: capacity increase to 800 Mg/a 12 June 2014: expansion of 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.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	SIEMENS fuel fabrication facility Karlstein unit Karlstein (BY)	Production of fuel elements from low-enriched uranium dioxide	Annual throughput of 400 Mg UO_2 up to a maximum of 4.0 % 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 August 1994 and 18 March 1996 Released from the Atomic Energy Act in March 1999	Fuel assembly production was discontinued; only manufactures conventional structural parts now (ANF Karlstein).
2	SIEMENS fuel fabrication facility Hanau MOX unit Hanau (HE)	Production of MOX fuel elements predominantly for LWRs from plutonium and uranium	Capacity approx. 35 Mg HM/a, expansion to 120 Mg HM/a was planned	Operating licence according to Section 9 of the Atomic Energy Act dated 16 August 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: September 2006.	The operator decided in April 1994 to not put the old unit back into service again. The production units have been demolished. No state supervision is required now. The demolition work was completed in July 2006.

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
3	SIEMENS fuel fabrication facility Hanau Uranium unit Hanau (HE)	Production of LWR fuel elements from low-enriched uranium	Capacity 1,350 Mg 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 (licensed according to Section 7 of the Radiation Protection Ordinance) has been completed.
4	Fuel fabrication facility NUKEM-A Hanau-Wolfgang (HE)	Production of 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 – except for a partial area of 1,000 m² 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.
5	Hochtemperatur-Brennelement-Gesellschaft (HOBEG) Hanau (HE)	Fabrication of spherical fuel elements for HTRs on the basis of uranium (up to 94 % U-235) and thorium	200,000 fuel elements/a 11.7 Mg 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 supervision under the Atomic Energy Act on 18 December 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 Storage Facilities for Fuel Elements[1]

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Transport cask storage at the Storage Facility North (ZLN) Rubenow (near Greifswald), MV	Storage of spent fuel elements from the Rheinsberg and Greifswald reactors in transport and storage casks (dry storage)	585.4 Mg 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 7 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	Gorleben storage facility for fuel elements (BZG) (formerly: Transport cask storage facility Gorleben (TBL-G)) NI	Storage of spent fuel elements in transport and storage casks as well as vitrified HAW fission products 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 canisters - 1 TS 28 V, - 74 CASTOR® HAW 20/28 CG, - 21 CASTOR® HAW28M-12 TN85.

[1] With their transfer to BGZ mbH, all BGZ mbH-owned interim storage facilities for the storage of nuclear fuel (both the central and the on-site interim storage facilities) have been given new, uniform designations. BASE was also informed in a letter from BGZ mbH dated 5 August 2019.

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
3	Ahaus storage facility for fuel elements (BZA) (formerly: Transport cask storage facility Ahaus (TBL-A)) NW	Storage of 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-300 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: Decentralised Storage Facilities for Fuel Elements[1]

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Neckarwestheim storage facility for fuel elements (BZN) (formerly: Neckarwestheim on-site interim storage facility) Gemmrigheim, BW	Storage of spent fuel elements from units GKN1 and GKN 2 of the - Neckar Joint Nuclear Power Plant	1,600 Mg of heavy metal in up to 151 transport and storage casks with up to $8.3 \cdot 10^{19}$ Bq activity and 3.5 MW heat release	As per Section 6 of the Atomic Energy Act on 22 Sept. 2003 1st amendment on 22 March 2006 2nd amendment on 28 Sept.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 November 2003 First storage: 6 December 2006 94 casks were stored at in the interim storage facility at the end of 2022.
2	Philippsburg storage facility for fuel elements (BZP) (formerly: Philippsburg on-site interim storage facility) BW	Storage of spent fuel elements from units 1 and 2 of 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 6th amendment on 19 March 2020 7th amendment on 1 October 2020 8th amendment on 27 October 2020	Start of building work: 17 May 2004 First storage: 19 March 2007 92 casks were in interim storage at the end of 2022.

[1] With their transfer to BGZ mbH, all BGZ mbH-owned interim storage facilities for the storage of nuclear fuel (both the central and the on-site interim storage facilities) have been given new, uniform designations. BASE was also informed in a letter from BGZ mbH dated 5 August 2019.

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
3	Storage at the Obrigheim NPP BW	Storage of spent fuel elements and nuclear components from the Obrigheim NPP (wet storage)	980 fuel elements (approx. 286 Mg HM)	As per Section 7 of the Atomic Energy Act on 26 October 1998	342 spent fuel elements were transported to the storage facility for fuel elements at Neckarwestheim between June and December 2017.
4	Grafenrheinfeld storage facility for fuel elements (BZR) (formerly: Grafenrheinfeld on-site interim storage facility) BY	Storage of spent fuel elements from the Grafenrheinfeld nuclear power plant	800 Mg of heavy metal in up to 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 September 2003 1st amendment on 31 July 2007 2nd amendment on 6 October 2011 3rd amendment on 3 November 2011 4th amendment on 26 April 2018 5th amendment on 15 November 2018 6th amendment on 16 December 2019	Start of building work: 22 September 2003 First storage: 27 February 2006 54 casks were in storage at the end of 2022.
5	Gundremmingen storage facility for fuel elements (BZM) (formerly: Gundremmingen on-site interim storage facility) BY	Storage of spent fuel elements - from units B and C of 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 6th amendment on 1 October 2020	Start of building work: 23 August 2004 First storage: 25 August 2006 115 casks were in storage at the end of 2022.

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
6	Isar storage facility for fuel elements (BZI) (formerly: Isar on-site interim storage facility) Niederaichbach BY	Storage of 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 September 2003 Immediate enforcement ordered on 28 May 2004 1st amendment on 11 January 2007 2nd amendment on 29 February 2008 3rd amendment on 16 November 2011 4th amendment on 7 February 2012 5th amendment on 20 June 2016 6th amendment on 28 July 2016 7th amendment on 9 Aug. 2017	Start of building work: 14 June 2004 First storage: 12 March 2007 88 casks were in storage at the end of 2022.
7	Biblis storage facility for fuel elements (BZB) (formerly: Biblis on-site interim storage facility) HE	Storage of spent fuel elements - from units A and B of the Biblis nuclear power plant Storage of vitrified HAW waste from Sellafield in up to seven CASTOR® HAW28M casks	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 September 2003 1st amendment on 20 October 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 September 2015 6th amendment on 7 April 2016 7th amendment on 14 December 2017 8th amendment on 14 June 2018 9th amendment on 19 December 2019	Start of building work: 1 March 2004 First storage: 18 May 2006 108 casks were in storage at the end of 2022.
8	Grohnde storage facility for fuel elements (BZD) (formerly: Grohnde on-site interim storage facility) NI	Storage of 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 4th amendment on 15 July 2020	Start of building work: 10 November 2003 First storage: 27 April 2006 37 casks were in storage at the end of 2022.

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
9	Lingen storage facility for fuel elements (BZL) (formerly: Lingen (Emsland) on-site interim storage facility) Bramsche NI	Storage of 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 July 2007 1st amendment on 1 Dec. 2008 2nd amendment on 19 Dec. 2014 3rd amendment on 7 Aug. 2015 4th amendment on 4 June 2020	Start of building work: 18 October 2000 First storage: 10 December 2002 47 casks were in storage at the end of 2022.
10	Unterweser storage facility for fuel elements (BZU) (formerly: Unterweser on-site interim storage facility) Rodenkirchen NI	Storage of 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 September 2003 Immediate enforcement ordered on 5 February 2007 1st amendment on 27 May 2008 2nd amendment on 5 January 2012 3rd amendment on 18 December 2012 4th amendment on 11 August 2016 5th amendment on 2 November 2017 6th amendment on 26 July 2018	Start of building work: 19 January 2004 First storage: 18 June 2007 40 casks were in storage at the end of 2022.
11	AVR cask storage facility at the FZJ Jülich NW	Storage of spent AVR fuel elements in CASTOR® transport and storage casks	Up to 300,000 AVR fuel rods in max. 158 CASTOR® THTR/AVR casks	Decision in accordance with Section 6 of the Atomic Energy Act of 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 containers have been at the interim storage facility since 2009. The current storage is based on a nuclear law order.

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
12	Krümmel storage facility for fuel elements (BZK) (formerly: Krümmel on-site interim storage facility), SH	Storage of 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 December 2003 1st amendment on 16 November 2005 Immediate enforcement ordered on 28 April 2006 2nd amendment on 17 October 2007 3rd amendment on 9 July 2014 4th amendment on 18 April 2016 5th amendment on 4 July 2016 6th amendment on 18 December 2018	Start of building work: 23 April 2004 First storage: 14 November 2006 42 casks were in storage at the end of 2022.
13	Brokdorf storage facility for fuel elements (BZF) (formerly: Brokdorf on-site interim storage facility) SH	Storage of spent fuel elements from the Brokdorf 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 28 November 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 35 casks were in storage at the end of 2022.

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
14	Brunsbüttel storage facility for fuel elements SH	Storage of 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 November 2003 Immediate enforcement ordered on 28 October 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 November 2015.	Start of building work: 7 October 2003 First storage: 5 February 2006 20 casks have been in storage since 2017. 9 casks were stored on the basis of the storage licence until 2013. 11 further casks have been stored since 2017 on the basis of a supervisory order. The supervisory order was extended without a specific time limit on 17 January 2020.

Table III. 6: Central storage facilities for radioactive waste[1]

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Gorleben radioactive waste storage facility (AZG) NI	Storage of radioactive waste with negligible heat generation from NPPs, medicine, research and industry	200-l, 400-l drums, type III concrete containers, type I-II cast-iron containers, type I-IV containers with a total activity of up to $5 \cdot 10^{18}$ Bq 15,000 m^3	Handling licences according to Section 3 StrlSchV[2] of 27 October 1983, 13 October 1987 and 13 September 1995	In operation since October 1984. Operator: BGZ mbH
2	Ahaus radioactive waste storage facility (AZA) NW	Storage of radioactive waste from NPPs	Konrad casks, 20' containers and unit parts, total activity restricted in the storage area I to $1\text{-}10^{17}$ Bq	Handling licences according to Section 7 StrlSchV[3] of 9 November 2009, latest handling licence according to Section 12 StrlSchG of 17 July 2020, limited until 31 December 2057.	In operation since July 2010. Operator: BGZ mbH
3	Storage facility of the EVU Mitterteich BY	Interim storage of waste with negligible heat generation from Bavarian nuclear facilities	40,000 waste packages (200-litre, 400-litre or cast-iron containers)	Handling licences according to Section 3 StrlSchV[18] of 7 July 1982	In operation since July 1987. Operator: Sammelstelle Bayern für radioaktive Stoffe GmbH (GRB)

[1] With their transfer to BGZ mbH, all BGZ mbH-owned interim storage facilities for radioactive waste have been given new, uniform designations.

[2] in the version of 13 October 1976 and 30 June 1989 respectively.

[3] In the 2001 version

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
4	Storage facility North (ZLN) Rubenow MV	Interim storage of operational and decommissioning waste from the Greifswald and Rheinsberg NPPs with interim storage of large dismantled components	165,000 m^3	Handling licence according to Section 3 StrlSchV[18] of 20 February 1998	In operation since March 1998.
5	Hauptabteilung Dekontaminationsbetriebe (HDB), now Entsorgungsbetriebe (EB) Karlsruhe BW	Storage of non-heat-generating waste from FZK, WAK, ITU, BW state collection point and also for third parties to a limited extent/to provide a buffer	Handling (conditioning and interim storage) of radioactive residues 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 November 1983, 36th amendment notice of 7 April 2017 according to Section 7 para. 1+2 StrSchV and Section 2 para. 1+3 AtG in storage building L566	In operation since December 1964. The storage bunker L563 for ILW waste operated by KTE will be extended by building L566. ILW waste products and raw waste are to be stored until post-conditioning suitable for final disposal, and the waste products conditioned suitable for disposal are to be stored in long-term interim storage.

Table III. 7: Reprocessing plant

No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Karlsruhe Reprocessing Plant (WAK) Eggenstein-Leopoldshafen, BW	Experimental plant for reprocessing and technology development	0.175 Mg of HM/day; approx. 40 Mg of UO_2/a	Operation WAK: 1st partial operating licence according to Section 7 AtG of 2 January 1967 Operation VEK1st partial operating licence for VEK dated 20 December 2005 2nd partial operating licence for VEK dated 24 February 2009 (nuclear [hot] commissioning) Decommissioning of WAK: 1st decommissioning licence, March 1993 23rd decommissioning licence dated 14 December 2011 to dismantle the LAVA high-active laboratory and the LAVA (hot) cells 26th decommissioning licence to remotely dismantle the VEK process equipment dated 6 July 2018 27th decommissioning licence dated 4 March 2021 (partial dismantling of a pipe bridge between the process building (PG) and the HWL) 28th decommissioning licence dated 1 June 2021(dismantling of a shielding wall of the process building) 29th decommissioning licence dated 14 October 2021 (dismantling of the water basin in the process building)	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. 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 November 2010. The HAWC was completely vitrified. This generated 140 receptacles 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 Storage Facility North since February 2011.

Table III. 8: Conditioning plants for fuel elements

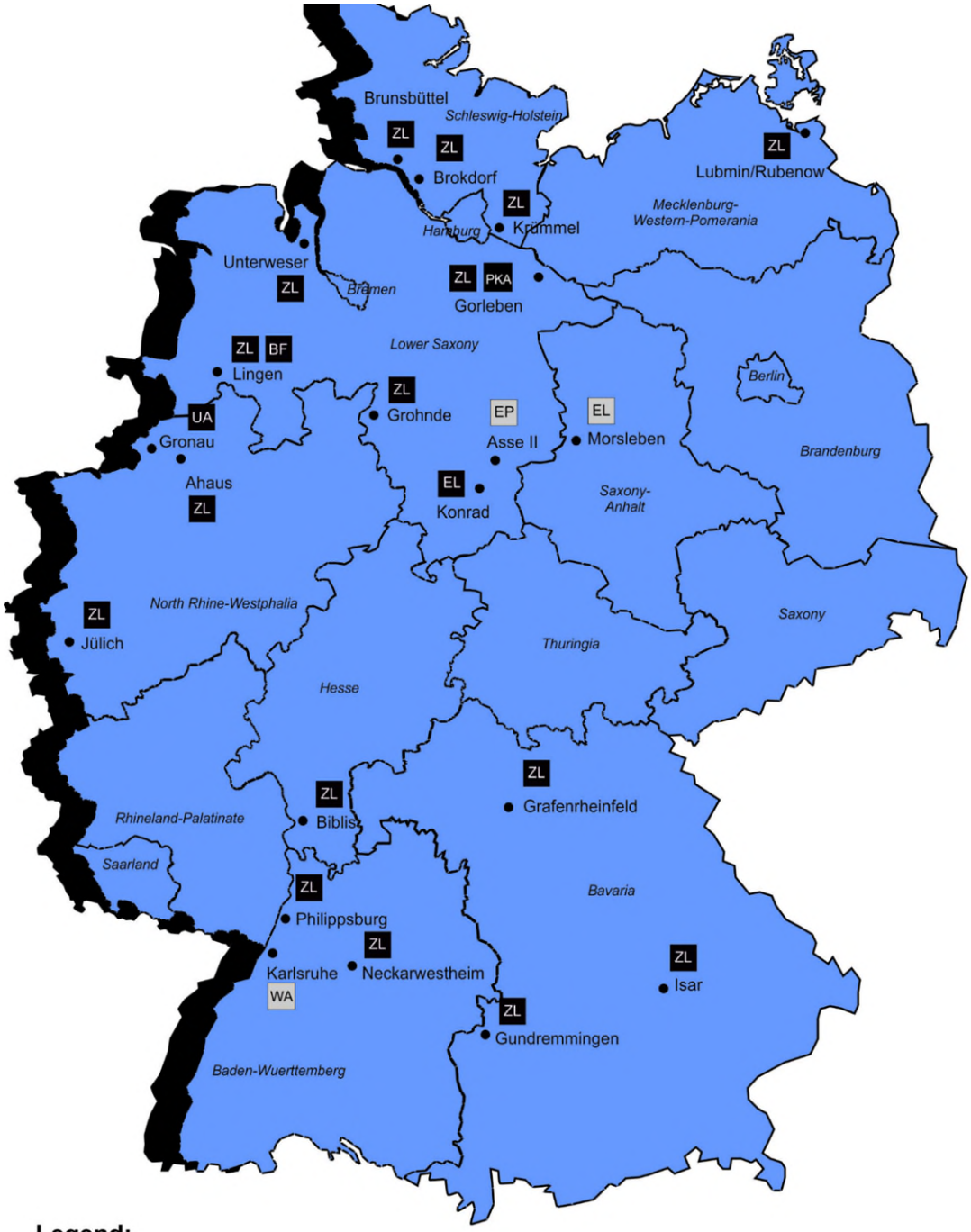
No.	Designation of the facility and location	Purpose of the facility	Capacity as per licence	Licence	Comments
1	Pilot conditioning plant (PKA) Gorleben, NI	Repair of damaged casks, conditioning of radioactive residues and waste (including spent fuel elements, fuel rods and fuel assembly components) for 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 January 1990 2nd partial licence dated 21 July 1994 (subsequent obligation 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 obligation under the 2nd partial licence guarantees the readiness to accept a damaged cask at any time. As soon as an alternative concept is available, the operator intends to dismantle the PKA.

Table III. 9: Disposal and decommissioning projects

No.	Designation of the facility and location	Purpose of the facility	Quantity disposed of/ activity	Licence	Comments
1	Konrad repository Salzgitter, NI	Disposal 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.	Designation of the facility and location	Purpose of the facility	Quantity disposed of/ activity	Licence	Comments
2	ASSE II mine Remlingen, NI	Initially: 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 September 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 mbH 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.	Designation of the facility and location	Purpose of the facility	Quantity disposed of/ activity	Licence	Comments
3	Morsleben disposal site for radioactive waste (ERAM), ST	Initially: 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: BfS declaration 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 September 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 a public hearing in October 2012, BGE mbH 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 of the current Ministry of Science, Energy, Climate Protection and the Environment of Saxony-Anhalt.



Legend:

UA	Uranium enrichment plant
BF	Fuel element fabrication plant
PKA	Pilot conditioning plant
WA	Reprocessing plant
ZL	Interim storage facility for high-level radioactive waste
EL	Radioactive waste repository
EP	Repository project
■	In operation/under construction
▢	Under decommissioning/decommissioning applied for

As of 31 December 2022

Fig. III. Nuclear supply and disposal sites [1]

[1] In the case of interim storage facilities, only interim storage facilities for high-level radioactive materials are included.