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Division S I 5 · Post office box 12 06 29 · 53048 Bonn · Germany

E-Mail: SI5@bmu.bund.de

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Abbreviations

ALARA	As Low As Reasonably Achievable
ASME	American Society of Mechanical Engineers
AtAV	Atomrechtliche Abfallverbringungsverordnung Nuclear Waste Shipment Ordinance
AtDeckV	Atomrechtliche Deckungsvorsorge-Verordnung Nuclear Financial Security Ordinance
AtEV	Atomrechtliche Entsorgungsverordnung Nuclear Waste Management Ordinance
AtG	Atomgesetz Atomic Energy Act
AtSKostV	Kostenverordnung zum Atomgesetz und zum Strahlenschutzgesetz Cost Ordinance under the Atomic Energy Act and the Radiation Protection Act
AtSMV	Atomrechtliche Sicherheitsbeauftragten- und Meldeverordnung Nuclear Safety Officer and Reporting Ordinance
AtVfV	Atomrechtliche Verfahrensverordnung Nuclear Licensing Procedure Ordinance
ATWS	Anticipated Transient Without Scram
AtZüV	Atomrechtlichen Zuverlässigkeitsüberprüfungs-Verordnung Nuclear Trustworthiness Verification Ordinance
AVR	Arbeitsgemeinschaft Versuchsreaktor Jülich Experimental reactor at Jülich
AVT	All Volatile Treatment
BAM	Bundesanstalt für Materialforschung und -prüfung Federal Institute for Materials Research and Testing
BBK	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe Federal Office of Civil Protection and Disaster Assistance
BfE	Bundesamt für Entsorgung Federal Office for the Safety of Nuclear Waste Management
BfS	Bundesamt für Strahlenschutz Federal Office for Radiation Protection
BGE	Bundesgesellschaft für Endlagerung mbH
BHB	Betriebshandbuch Operating manual
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWi	Bundesministerium für Wirtschaft und Energie Federal Ministry for Economic Affairs and Energy
BWR	Boiling Water Reactor
CCF(s)	Common Cause Failure(s)
CNS	Convention on Nuclear Safety
CONVEX	Convention Exercises
CSS	Commission on Safety Standards

DIN	Deutsches Institut für Normung German Institute for Standardization
ECURIE	European Community Urgent Radiological Information Exchange
EIA	Environmental Impact Assessment
ELAN	Elektronische Lagedarstellung für den Notfallschutz Electronic situation display for emergency preparedness
EN	Europäische Norm European standard
EnBW	Energie Baden-Württemberg AG
EndlagerVlV	Endlagervorausleistungsverordnung Repository Prepayment Ordinance
EnKK	EnBW Kernkraftwerk GmbH
ENSREG	European Nuclear Safety Regulator Group
EPreSSC	Emergency Preparedness Safety Standard Committee
ERAM	Endlager für radioaktive Abfälle Morsleben Morsleben Repository for Radioactive Waste
ESK	Entsorgungskommission Nuclear Waste Management Commission
EU	European Union
Euratom	European Atomic Energy Community
gGmbH	Gemeinnützige Gesellschaft mit beschränkter Haftung Non-profit limited liability company
GfS	Gesellschaft für Simulatorschulung mbH
GG	Grundgesetz Basic Law of the Federal Republic of Germany
GmbH	Gesellschaft mit beschränkter Haftung Limited liability company
GMLZ	Gemeinsames Melde- und Lagezentrum von Bund und Ländern German Joint Information and Situation Centre
GNSSN	Global Nuclear Safety and Security Network
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH
HERCA	Heads of European Radiation Control Authorities
HGF	Helmholtz-Gesellschaft Helmholtz Association
HMN	Handbuch für mitigative Notfallmaßnahmen Accident mitigation manual
IAEA	International Atomic Energy Agency)
ICRP	International Commission on Radiological Protection
IEC	International Electrotechnical Commission
IMIS	Integriertes Mess- und Informationssystem zur Überwachung der Umweltradioaktivität Integrated Measuring and Information System for the Monitoring of Environmental Radioactivity
IMS	Integrated Management System

INES	International Nuclear and Radiological Event Scale
INEX	International Nuclear Emergency Exercises
INFCIRC	Information Circular
IRRS	Integrated Regulatory Review Service
IRS	International Reporting System on Operating Experiences
ISO	International Organization for Standardization
KFÜ	Kernkraftwerks-Fernüberwachungssystem Remote monitoring system for nuclear power plants
KHG	Kerntechnische Hilfsdienst GmbH
KIV	Kaliumiodidverordnung Potassium Iodide Ordinance
KTA	Kerntechnischer Ausschuss Nuclear Safety Standards Commission
KWU	Kraftwerk Union AG
LAA	Länderausschuss für Atomkernenergie *Länder* Committee for Nuclear Energy
MoWaS	Modulares Warnsystem Modular warning system
MOX	Mixed oxide
MSK scale	Medvedev-Sponheuer-Kárník scale
NDWV	Notfall-Dosiswerte-Verordnung Emergency Dose Level Ordinance
NHB	Notfallhandbuch Emergency manual
NINA	Notfall-Informations- und Nachrichten-App des Bundes Emergency Information and News App of the Federation
NUSSC	Nuclear Safety Standards Committee
OECD/NEA	Organisation for Economic Co-operation and Development/Nuclear Energy Agency
OILs	Operational Intervention Levels
PAR	Passive Autokatalytische Rekombinatoren Passive autocatalytic recombiners
PBO	Personelle Betriebsorganisation Plant personnel organisation
PNS	Portal for Nuclear Safety
PSA	Probabilistic Safety Analysis
PWR	Pressurised Water Reactor
RANET	Response and Assistance Network
RASSC	Radiation Safety Standards Committee
REI	Richtlinie zur Emissions- und Immissionsüberwachung kerntechnischer Anlagen Guideline on Emission and Immission Monitoring of Nuclear Installations

RFÜ	Radiologische Fernüberwachung kerntechnischer Anlagen/ Reaktorfernüberwachung kerntechnischer Anlagen Remote radiological monitoring of nuclear installations/ Remote reactor monitoring of nuclear installations
RHWG	Reactor Harmonization Working Group der WENRA
RLB	Radiologisches Lagebild Radiological situation report
RLZ	Radiologisches Lagezentrum des Bundes Federal Radiological Situation Centre
RODOS	Real-Time Online Decision Support System
RPV	Reactor Pressure Vessel
RSK	Reaktor-Sicherheitskommission Reactor Safety Commission
SAMG	Severe Accident Management Guidelines
SatWaS	Satellitengestütztes Warnsystem Satellite-based warning system
SMS	Safety management system
SSK	Strahlenschutzkommission Commission on Radiological Protection
StandAG	Standortauswahlgesetz Site Selection Act
StGB	Strafgesetzbuch German Criminal Code
StrlSchG	Strahlenschutzgesetz Radiation Protection Act
StrlSchV	Strahlenschutzverordnung Radiation Protection Ordinance
SÜ	Sicherheitsüberprüfung Safety Review
SZL	Standortzwischenlager On-site storage facility
TBL	Transportbehälterlager Transport cask storage facility
TRANSSC	Transport Safety Standards Committee
TÜV	Technischer Überwachungs-Verein Technical Inspection Agency
UVP	Umweltverträglichkeitsprüfung Environmental Impact Assessment (EIA)
UVPG	Gesetz über die Umweltverträglichkeitsprüfung Act on the Assessment of Environmental Impacts
VD NS	Vienna Declaration on Nuclear Safety
VdTÜV	Verband der Gutachterorganisation der TÜV Association of Technical Inspection Agencies
VGB	VGB PowerTech e. V., “Technische Vereinigung der Großkraftwerksbetreiber”

VGB-SBS	VGB-Sicherheitskulturbewertungssystem VGB safety culture assessment system
VGB-ZMA	Zentrale Melde- und Auswertungsstelle des VGB Central Incident Reporting and Evaluation Office of VGB
WAK	Wiederaufarbeitungsanlage Karlsruhe Karlsruhe reprocessing plant
WANO	World Association of Nuclear Operators
WASSC	Waste Safety Standards Committee
WGOE	Working Group on Operating Experience der WENRA
WENRA	Western European Nuclear Regulators Association
WENRA SRLs	WENRA safety reference levels
WGE	Working Group Emergencies der HERCA
WLN	Weiterleitungsnachricht Information notice
ZdB	Zentralstelle des Bundes Central Federal Agency

Introduction

With the 13th Atomic Energy Act (AtG) amendment, which came into force on 6 August 2011, Germany has enshrined in law the phase-out of the use of nuclear energy for the commercial generation of electricity by 31 December 2022 at the latest. For the nuclear installations still in operation, ensuring a high level of safety remains a highest priority for the Federal Government.

Germany is committed to its international obligations, especially to the fulfilment of the obligations under the Convention on Nuclear Safety (CNS). The Federal Government regards this Convention as an important instrument for the maintenance and continuous improvement of nuclear safety both in Germany and worldwide.

The eighth National Report of the Government of the Federal Republic of Germany under the Convention on Nuclear Safety was prepared jointly by the nuclear licensing and supervisory authorities of the Federation and the *Länder* as well as by the Technical Association of Large Power Plant Operators VGB PowerTech e.V. (VGB).

This report follows the provisions of guideline INFCIRC/572/Rev.6 in terms of content. In addition to the nuclear installations as defined by the Convention, Germany has also voluntarily been reporting on the research reactors operated in Germany since the Third Review Meeting in 2005.

The relevant laws, ordinances and regulations are indicated for each article of the Convention. Each article describes how the essential safety requirements are fulfilled by the German nuclear installations and what measures have been taken to this end by the licence holders of these nuclear installations.

In addition to current developments, this report focuses in particular on

- the results of the Seventh Review Meeting in 2017,
- the focal points of the questions put to Germany at the Seventh Review Meeting, and
- the results of the consultations of Country Group 4 of the Seventh Review Meeting.

The terms used in this report for the designation of certain functions of persons encompass all persons irrespective of their gender.

The German report for the Eighth Review Meeting in 2020 was adopted by the Cabinet of the Federal Government at its meeting on 12 June 2019.

Summary

In 1994, the Federal Republic of Germany signed the Convention on Nuclear Safety (CNS) and since then has been reporting regularly within the framework of the review meetings. The Federal Government notes that Germany fulfils all its obligations under the Convention on Nuclear Safety as well as the three principles of the Vienna Declaration on Nuclear Safety (VD NS). Compliance with these principles is set out in Articles 6, 14, 17, 18 and 19.

At the Seventh Review Meeting in 2017, Germany received very good appreciation within Country Group 4. Germany successfully implemented five of the six challenges from the Sixth Review Meeting. In the field of safety culture, the German KOMFORT system was identified as an “area of good performance”. This indicator-based system systematically collects and evaluates observations made within the framework of supervision on aspects related to safety culture.

During the Seventh Review Meeting, two new challenges were formulated for Germany. These were successfully implemented by Germany by the Eighth Review Meeting and are briefly described below:

Challenge 1 — Implementation of the Western European Nuclear Regulators Association Safety Reference Levels (WENRA SRLs) into the German regulations
The implementation of the WENRA SRLs into the national regulations is in the final phase of agreement and coordination and will be completed by the Review Meeting in 2020. Detailed reporting on this is provided in Article 7.

Challenge 2 — Preparation and implementation of the Integrated Regulatory Review Service (IRRS) mission in 2019
In the run-up to the IRRS mission in Germany, a comprehensive self-assessment was carried out and identified improvement measures were recorded in a national action plan. The IRRS mission itself took place from 31 March to 12 April 2019. The challenge has thus been implemented. Detailed reporting on the results of the IRRS mission is provided under Article 8.

In addition to the two challenges of the Seventh Review Meeting, one challenge from the Sixth Review Meeting was still pending:

Developing criteria and standards to lift measures after an event with major release and allowing the population to return to affected areas.

With the reorganisation of radiation protection law, an independent Radiation Protection Act, the new Radiation Protection Ordinance and the Emergency Dose Level Ordinance came into force on 31 December 2018. The provisions for emergency situations and the regulations for monitoring environmental radioactivity already came into force on 1 October 2017. The challenge has been implemented with the legal requirements for emergency preparedness and response, which, among other things, provide for the inclusion of criteria for the lifting of measures in the general emergency plan of the Federation.

In the review period (2017 - 2019), no incidents within the meaning of the international reporting system occurred at German nuclear installations. This is due to the high safety level of German nuclear installations, which is maintained or improved by continual backfitting. Essential means for identifying appropriate retrofitting possibilities are the evaluation of the feedback of national and international operating experience as well as monitoring of the state of the art in science and technology. In the period under review, there were some indications of optimisation possibilities. Examples of derived measures are described in Article 6. The RSK has published eight statements on key safety issues since the National Report for the Seventh Review Meeting. These are briefly described under Article 6.

Internationally, Germany is actively involved in the further development of the IAEA safety standards and the WENRA regulations. In particular, the Federal Republic of Germany is actively involved in working on the current safety issues discussed in the Reactor Harmonization Working Group (RHWG) of WENRA, e.g. safety demonstration on practical elimination and assessment of passive safety systems, but also in the further development of basic requirements, i.e. the WENRA Safety Reference Levels for Existing Reactors (→ Article 7).

Since the seventh National Report under the Convention on Nuclear Safety, work has continued on updating the safety standards of the Nuclear Safety Standards Commission (KTA). An update of all safety standards will be completed by the Eighth Review Meeting (→ Article 7). Thus, the safety standards of the KTA will be up to date by the end of the use of nuclear energy for the commercial generation of electricity by 31 December 2022 at the latest.

6 Existing nuclear installations

ARTICLE 6 EXISTING NUCLEAR INSTALLATIONS

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

Overview of the nuclear installations

Germany has a total of 17 nuclear installations (→ Figure 6-1). Of these 17 nuclear installations, seven are in power operation at seven sites with a total gross capacity of 10,013 MWe (→ Appendix 1-1a). In the other ten installations (one in the post-operational phase, nine under decommissioning) the fuel is still inside the installations, either still in the spent fuel pools or in storage casks (CASTOR) in the storage facilities at the respective sites. A complete overview of all power reactors and prototype reactors in Germany that are in power operation, under decommissioning, permanently shut down or dismantled is shown in Appendix 1.

Based on the 13th Act Amending the Atomic Energy Act (13th AtG amendment) in 2011, the power operation licences for the commercial generation of electricity of the nuclear installation Krümmel (commissioned in 1984) and the seven oldest nuclear installations, commissioned up to and including 1980, expired. In 2011, it was further stipulated in the Atomic Energy Act (AtG) that the licences for power operation of the nine nuclear installations still in operation at that time will successively expire by 31 December 2022 at the latest (§ 7(1a) sentence 1 AtG).

The first decommissioning licence for the nuclear installation Grafenrheinfeld, permanently taken out of operation on 27 June 2015, was issued on 11 April 2018. The nuclear installation Gundremmingen B, permanently shut down on 31 December 2017, was granted its first decommissioning licence on 19 March 2019.

According to the AtG, Unit 2 at the Philippsburg site will permanently cease power operation by 31 December 2019 at the latest. After this date, only six nuclear installation will be in operation in the Federal Republic of Germany.

The following nuclear installations still in power operation have already submitted an application for decommissioning and dismantling:

- Neckarwestheim Unit II: 18 July 2016
- Philippsburg Unit 2: 18 July 2016
- Emsland: 22 December 2016
- Grohnde: 26 October 2017
- Brokdorf: 1 December 2017

The 17 German nuclear installations for commercial electricity generation shown in Figure 6-1 can be divided into three construction lines for pressurised water reactors (PWRs) and two construction lines for boiling water reactors (BWRs) according to the designs when they were built. The classification of the individual nuclear installations according to construction lines can be found in Appendices 1-1a and 1-1b. Appendix 3 contains a compilation of technical details on the nuclear installations of the various construction lines still in operation. Fundamental safety-relevant plant characteristics are listed for the areas of reactor coolant pressure boundary, emergency core cooling, containment, limitations and safety I&C (including reactor protection), electrical power supply as well as protection against external hazards.

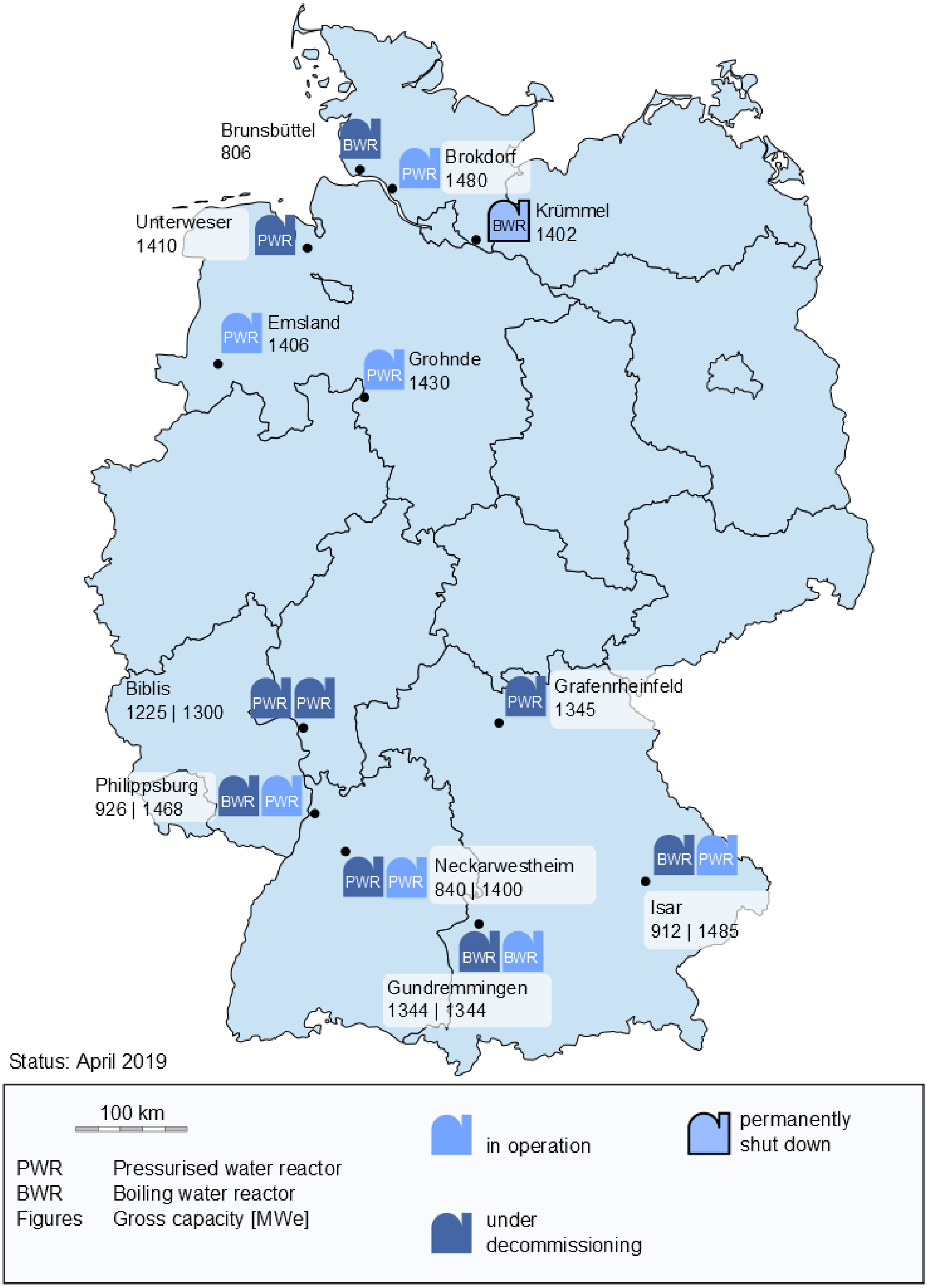

Figure 6-1 Nuclear installations for electricity generation

Operation of the nuclear installations

In 2018, gross electricity generation in Germany was 646.8 TWh[1]. Nuclear power accounts for 11.8 % of this total.

In 2017, gross electricity generation was 653.6 TWh. In 2017, nuclear power accounted for 11.7 % of this total.

Table 6-1 shows the average availabilities of the German nuclear installations. Since the energy availability is the product of capacity and time availability, the average energy availability of all German nuclear installations may be higher than the average time availability.

Table 6-1 Average availabilities of German nuclear installations

Year	Time availability in %	Energy availability in %	Energy utilisation in %
2018	90.9	89.7	86.2
2017	82.0	80.2	76.3
2016	88.9	88.4	84.4
2015	91.8	91.2	82.2
2014	90.6	89.1	86.8
2013	89.2	88.7	87.2
2012	91.0	90.5	88.9
2011	82.1	81.9	68.2
2010	76.4	77.5	74.0
2009	73.2	74.2	71.2
2008	80.0	80.9	78.4
2007	76.0	76.4	74.4

Time availability: available operating time/calendar time
Energy availability: possible energy generation/nominal energy
Energy utilisation: actual energy generation/nominal energy

Use of mixed-oxide fuel

The plutonium obtained from the reprocessing of spent fuel from German nuclear installations in other European countries (France and Great Britain) is utilised by the use of MOX (mixed-oxide) fuel in nuclear installations.

In Germany, MOX fuel is used in nuclear installations due to the utilisation obligation under § 9a(1) AtG. Since 1 July 2005, the transport of spent fuel for reprocessing has been banned. The separated plutonium from spent fuel that was brought into reprocessing before 1 July 2005 was completely processed in the form of MOX fuel and reused in the respective nuclear installations. Thus, the utilisation of the entire separated plutonium has fully been completed by reuse.

Modification licences

From 2016 to 2018, one technical modification licence for operation was granted for the nuclear installations. This licence was issued for Gundremmingen Unit C according to § 7(1) AtG for the use of fuel of the Atrium 11 type (KRB II C – 16th modification licence of 22 January 2018).

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1 Development of energy supply 2018: “Entwicklung der Energieversorgung 2018”, BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. (German Association of Energy and Water Industries), preliminary figures (status: March 2019)

Post-operational phase

One of the ten nuclear installations, Krümmel, whose power operation licence has already expired in accordance with the 13th AtG amendment, is currently in the post-operational phase. The application for decommissioning and dismantling of this installation was filed on 24 August 2015.

Research reactors

Research reactors are not nuclear installations as defined by the Convention. Report on them is given in compliance with the recommendation stated in the document “Code of Conduct on the Safety of Research Reactors” issued by the International Atomic Energy Agency (IAEA) in 2004.

In Germany, seven research reactors are operated with thermal outputs between 100 mW and 20 MW (→ Appendix 2-1a). The licence holders of the research reactors are public or state-sponsored universities and research centres. Three of these reactors with thermal outputs in the range between 100 kW and 20 MW are operated primarily as neutron sources for research. The BER II research reactor with a thermal capacity of 10 MW will permanently cease operation by 31 December 2019 at the latest. The application for decommissioning was filed on 24 April 2017. The remaining four research reactors are training reactors with a thermal output of 100 mW and 2 W respectively. These are operated for the purpose of practical training in the fields of reactor physics and radiation protection at the universities of Furtwangen, Stuttgart, Ulm and Dresden.

Three research reactors have been permanently shut down (→ Appendix 2-1b), and seven research reactors are under decommissioning and being dismantled (→ Appendix 2-2). Figure 6-2 shows the sites of research reactors (in December 2018).

For licensing and supervision of research reactors, the safety regulations for power reactors are applied, among others, by analogy. Depending on the risk potential of the respective research reactor, a multi-level approach is applied by the nuclear licensing and supervisory authorities of the *Länder*.

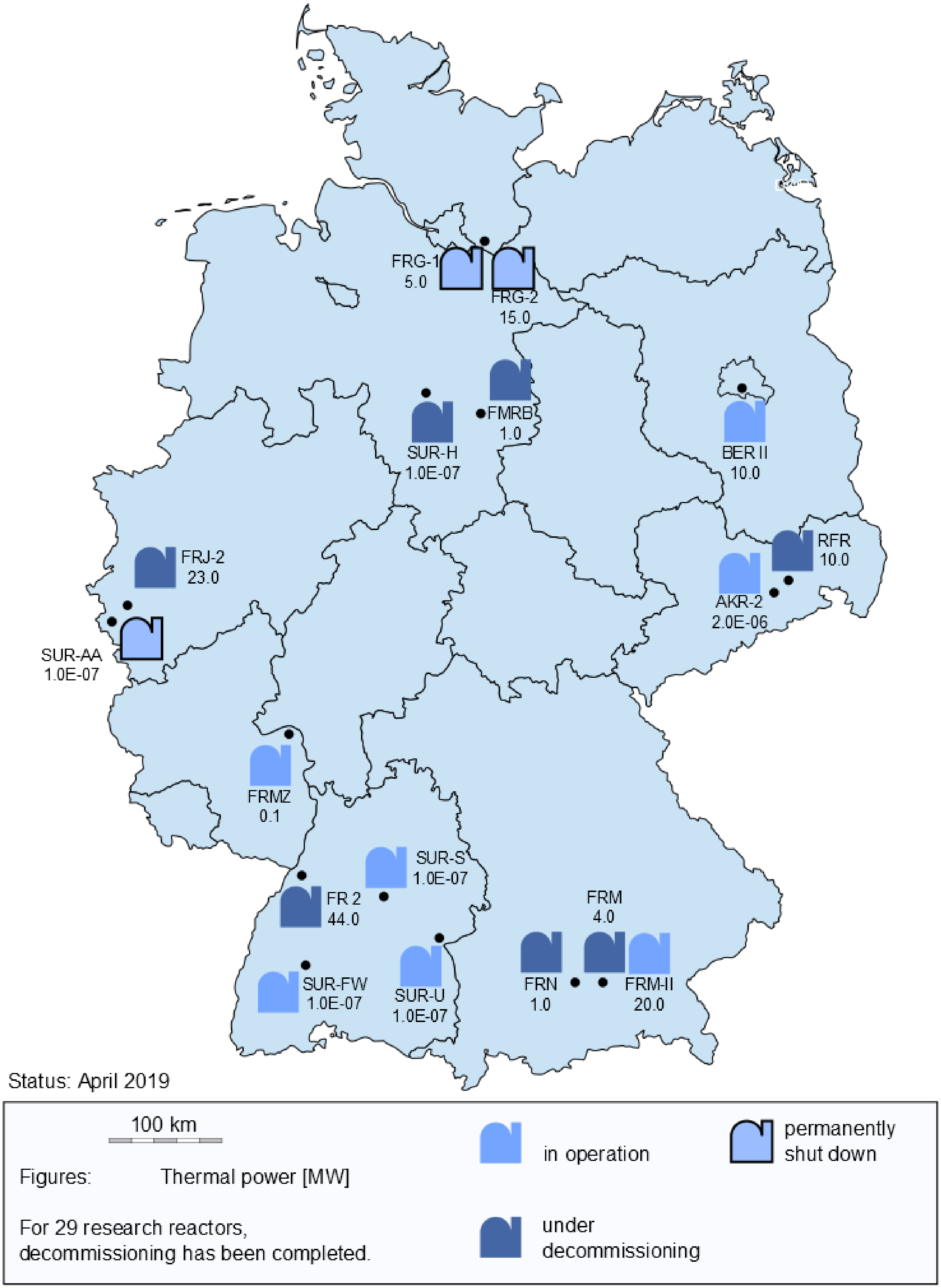

Figure 6-2 Research reactors in Germany

Other nuclear installations

To complete the picture of the application of nuclear energy in Germany, a brief overview is given of other nuclear installations which are also outside the scope of the Convention. However, some of these nuclear installations are subject to the “Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management” (Joint Convention), on which Germany last reported within the framework of the Sixth Review Meeting in May 2018.

In 2018, a total of 24 nuclear installations (power reactors as well as experimental and demonstration reactors) were under decommissioning. Of these, only the thorium high-temperature reactor is in “safe enclosure” status (→ Appendix 1-2). The nuclear installations Heißdampfreaktor Großwelzheim, Kernkraftwerk Niederaichbach and the Versuchsatomkraftwerk Kahl have already been completely dismantled and are thus released from the scope of the AtG (→ Appendix 1-3).

The other nuclear installations include facilities of the nuclear fuel cycle and waste management facilities (excluding facilities for storage and disposal). These are the uranium enrichment plant in Gronau and the fuel assembly fabrication plant in Lingen. The Karlsruhe reprocessing plant (WAK) permanently ceased operation in 1991 and has been in the process of dismantling since 1993. Several fuel fabrication plants have been completely dismantled.

In the Federal Republic of Germany, spent fuel from the operation of power and research reactors is stored in central storage facilities (Ahaus transport cask storage facility (TBL), TBL Gorleben and the storage facility Zwischenlager Nord in the vicinity of Greifswald), in decentralised storage facilities (cask storage facility of the “Arbeitsgemeinschaft Versuchsreaktor (AVR) Jülich”) and in storage facilities at the sites of the nuclear installations. The licences for these storage facilities are issued by the Federal Office for the Safety of Nuclear Waste Management (BfE). In principle, the licences are limited to 40 years. The obligation of the nuclear installation licence holders to store the spent fuel from the operation of the respective installations at the sites of the nuclear installations in order to avoid transports was laid down in the AtG in 2002. The transfer of spent fuel from nuclear installations for the commercial generation of electricity to a reprocessing plant and thus the transport of spent fuel to France or Great Britain was only possible until 30 June 2005.

From 1971 to 1991 and 1994 to 1998, low- and intermediate-level radioactive waste was disposed of in the Morsleben repository (ERAM). The ERAM is the first repository in deep geological formations to be closed following a plan approval procedure under nuclear law with public participation. The nuclear plan approval procedure is currently being conducted in accordance with the provisions of the Nuclear Licensing Procedure Ordinance (AtVfV). In April 2017, the Bundesgesellschaft für Endlagerung mbH (BGE) assumed operator responsibility for the ERAM. It thus also assumed the role of the applicant in the licensing procedure for closure. Nuclear supervision of the ERAM is exercised by the BfE. The BGE is currently carrying out extensive work to supplement the documents for the plan approval procedure in accordance with the recommendations of the Nuclear Waste Management Commission (ESK) and on additional requirements imposed by the authorised experts of the Ministry of Environment, Agriculture and Energy of Saxony-Anhalt. Among other things, proof is to be provided that the sealing structures described in the concept can be realised structurally.

From 1969 to 1978, low- and intermediate-level radioactive waste was emplaced in the Asse II mine. On 1 January 2009, the then competent Federal Office for Radiation Protection (BfS) assumed responsibility for the operation of the Asse II mine under mining and nuclear law. The BfS was assigned the task to safely close the Asse II mine in accordance with nuclear law. On 25 April 2017, the operatorship of the then competent BfS was transferred to the BGE. Supervision of the Asse II mine under nuclear and radiation protection law is carried out by the BfE. According to an amendment of § 57b AtG with the “Lex Asse”[2] of 24 April 2013, closure is to take place after retrieval of the radioactive waste.

[2] “Gesetz zur Beschleunigung der Rückholung radioaktiver Abfälle und der Stilllegung der Schachtanlage Asse II”, Federal Law Gazette Part I p. 921

The plan approval procedure for the Konrad repository was concluded with the plan approval decision of 22 May 2002, which became final by decision of the Federal Administrative Court of 26 March 2007. Since then, the existing former iron ore mine has been converted into the Konrad repository. After completion of the conversion work, it is expected to be commissioned as a repository for radioactive waste with negligible heat generation in 2027. The licence holder of the Konrad repository is the BGE. Nuclear and radiation protection supervision is exercised by the BfE.

The site for a repository especially for high-level radioactive waste is to be legally determined in a site selection procedure by 2031. To this end, the Site Selection Act (StandAG) was passed on 23 July 2013. The Commission on the Storage of High-Level Radioactive Waste had the task of evaluating in particular the site selection procedure by mid-2016 and developing the criteria for the search for and selection of a repository site. On the basis of the Commission's results, the legislator has amended the site selection procedure. The BfE supervises the site selection procedure and informs and involves the public. The BGE acts as the project implementer.

Work in the Gorleben exploration mine was interrupted in 2000 for a period of ten years. Following its resumption in October 2010, exploration was suspended again in November 2012. With the entry into force of § 29 StandAG, the mining-related exploration of the Gorleben salt dome was ended on 27 July 2013. In June 2015, the then responsible BfS submitted a comprehensive concept to the mining authority of the *Land* for keeping the mine open. The work for the transfer of the mine into an operating condition intended solely to keep it open will be carried out in accordance with the main operating plan for the Gorleben mine. On 25 April 2017, the tasks of the licence holder were transferred to the BGE.

Overview of important safety issues including selected events

In the following, reportable events are presented that occurred after the editorial deadline for the seventh National Report to the Convention on Nuclear Safety (CNS).

Within the framework of the processing of reportable events, deceptions and irregularities in the execution of work during in-service inspections (ISIs) of the radiation/activity monitoring at a site with two nuclear installations were detected in 2016. During the subsequent repetitions of the ISIs, an incorrectly set alarm value was also detected at a measuring point. This could have been detected earlier during the preceding ISIs, where a test emitter deviating from the test instruction was used, if it had been carried out correctly. The main causes identified were organisational weaknesses in the ISI process and a lack of controls by superiors with the result that these deceptions and irregularities were not detected at an early stage. Various improvement measures were taken in the organisational area, including the introduction of a control instrument by which the proper and on-schedule ISI implementation is randomly checked by an on-site control. Furthermore, a different person responsible for execution is appointed, as far as possible, with regard to expertise and qualification requirements as well as availability at scheduled dates than was the case with the preceding ISI.

During the scheduled refuelling of a PWR plant in 2017, anomalies in the upper part of the fuel rods were detected during a routine visual inspection of fuel assemblies. Further investigations showed that the detected anomalies in the form of flaking, discoloration or high oxide layer thicknesses were caused by corrosion of the fuel rod cladding tubes, which clearly exceeds the extent known from operating experience with the material concerned. For this material, a burn-up-dependent oxide layer thickness is given which reaches up to approx. 40 µm for a burn-up of 70 MWd/kgU. In the nuclear installation concerned, the permissible limit for the oxide layer thickness for the operation of the installation was exceeded by 100 µm or 130 µm locally, averaged over the circumference, at individual fuel rods. All fuel assemblies affected are of the same type. The cladding tubes of these fuel assemblies were predominantly manufactured from one ingot (casting block), though not all cladding tubes of this batch are affected and the extent of excessive corrosion or oxide flaking among the affected fuel rods varies. A final result of the cause analysis is not available. A first interim result shows that almost exclusively fuel assemblies of a subsequent delivery are affected. Measures were taken to avoid recurrence, including a reduction of reactor power and coolant temperature, narrow tolerances of operation modes during load changes, for hydrogen injections and material specifications. After a further cycle, all reused or new fuel assemblies showed only a slight increase in oxide layer thickness. Fuel assemblies with a very thick oxide layer were not reused.

During the review period (2017 - 2019), no events of INES level 1 or higher occurred at German nuclear installations.

Between the deadline for the National Report for the Seventh Review Meeting and the beginning of the review period for the Eighth Review Meeting, the reportable event “Damaged threaded bolts at support structures of ventilation ducts in the emergency feed building” of Category S (immediate report) was reported on 20 December 2016, which was classified as INES 1. Here, it was detected on support structures of ventilation ducts in the emergency feed building of a nuclear installation that some threaded bolts of the wall mounts were damaged or completely broken in more than one redundancy. According to current knowledge, the reason for this was that steel angle plates fitted to the ceiling lay on the wall mounts. To control vibrations, e.g. after an aircraft crash, the inner walls are separated from the ceiling by a 15 cm high joint. However, elements attached to the building components, such as the steel angle plates and wall mounts, did not consistently maintain this distance. Several modification measures were carried out for optimisation, e.g. disassembly of the steel angle plates and modifications to the mounts in order to exclude any impairment due to relative displacements in the future. The examination of comparable joints in other buildings did not reveal any corresponding findings.

Safety-related recommendations of the Reactor Safety Commission (RSK)

Between 2016 and 2018, the RSK published a total of eight statements on important safety issues related to nuclear installations in Germany. The statements were submitted on the following topics:

- Aspects of the determination of the site-specific design basis flood
- Damage to fuel assembly alignment pins and core component
- Monitoring of know-how and motivation loss and suitable measures for strengthening motivation and maintaining know-how in the German nuclear energy industry
- Lightning with parameters above the standard lightning current parameters
- Evaluation of the implementation of RSK recommendations of the Safety Review of German research reactors
- Boundary conditions for design basis accident analyses
- Evaluation of the implementation of RSK recommendations in response to Fukushima
- RSK summary statement on man-made hazards, aircraft crash – Reference report: Definition of load assumptions and assessment of Konvoi plants (construction line 4)

During the review period, the RSK prepared an evaluation of the implementation of the actions after the reactor accident in Fukushima in 2011 by the licence holders of nuclear installations and assessed the results in the statement “Evaluation of the implementation of RSK recommendations in response to Fukushima”[3] for PWRs and BWRs.

Against the background of the reactor accident in Fukushima, the RSK was requested to carry out a Safety Review of three research reactors in operation in addition to the German power reactors. In its “Evaluation of the implementation of RSK recommendations of the Safety Review of German research reactors”[4], the RSK emphasises that the recommendations made in 2012 have already largely been implemented. Special attention was drawn to the revision of the accident management

[3] RSK statement “Stellungnahme „Bewertung der Umsetzung von RSK-Empfehlungen im Nachgang zu Fukushima“, adopted at the 496th meeting of the RSK on 6 September 2017

[4] RSK statement “Bewertung der Umsetzung der Empfehlungen der RSK aus der Sicherheitsüberprüfung deutscher Forschungsreaktoren“, adopted at the 492nd meeting of the RSK on 22 March 2017

concepts, the reassessment of the robustness against beyond-design-basis earthquakes and the analyses of the effects of an aircraft crash.

The RSK formulated supplementary requirements for safety analyses for an event on level of defence 3 (design basis accident analysis) for a late or long-term design basis accident phase in the “Boundary conditions for design basis accident analyses”[5].

The RSK performs a robustness analysis with respect to the man-made hazard of an aircraft crash. In the report “RSK summary statement on man-made hazards, aircraft crash – Reference report: Definition of load assumptions and assessment of Konvoi plants”[6], the RSK draws the conclusion that it is shown that even in the case of a deliberate crash of a large commercial aircraft onto one of the nuclear installations of construction line 4 (Konvoi) still in operation, the cooling of the fuel in the reactor and the spent fuel pool will be maintained so that releases of radioactive material due fuel damage are not to be expected.

Overview of planned programmes and measures for continuous improvement of safety

The safety of the nuclear installations is continuously reviewed in an on-going process within the framework of nuclear regulatory supervision. If there are any new findings important to safety, their applicability to other nuclear installations and the need for any possible backfitting measures is examined (→ Article 8).

In order to maintain the high level of safety culture, the licence holders shall provide training in personnel actions for their own personnel. The training contents are conveyed for specific target groups (electrical engineering, mechanical engineering, radiation protection, dismantling) with changing focal points (e.g. communication, feedback culture, findings from near-miss events). Some of the training takes place on newly established training paths at the sites.

Research for the safety of nuclear installations

For the Federal Government, the safe operation of the nuclear installations in Germany but also in the neighbouring countries has top priority. Research projects to assess the safety of the operation of nuclear installations are continued. The aim of research funding is to maintain and expand the competence important to safety for the assessment and further development of the safety of nuclear installations in other countries, including new reactor concepts, even after the cessation of power operation of the nuclear installations in Germany.

International developments are monitored, and it is examined to what extent objectives for increasing reactor safety, proliferation resistance (in the case of research reactors) and reducing radioactive waste and safe waste storage can be achieved and possibly can be used to the advantage of Germany.

Through the funding priority “reactor safety research” of the Federal Ministry of Economics and Technology (BMWi), the Federal Republic of Germany participates in the international advancement of the safety of nuclear installations by performing its own, independent research. This includes participation in international research and development projects. Especially, Germany participates in safety-oriented experimental research projects under the auspices of OECD/NEA (Organisation for Economic Co-operation and Development/Nuclear Energy Agency). The strategic objectives pursued by the Federal Government with its funding measures and the topics of reactor safety research to be dealt with in the future are described in the 7th Energy Research Programme of the Federal

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5 RSK statement “Randbedingungen der Nachweisführung zur Störfallbeherrschung”, adopted at the 492nd meeting of the RSK on 22 March 2017

6 RSK statement “Zusammenfassende Stellungnahme der RSK zu zivilisatorisch bedingten Einwirkungen, Flugzeugabsturz; Teilbericht: Festlegung der Lastannahmen und Bewertung der Konvoi-Anlagen”, adopted at the 499th meeting of the RSK on 6 December 2017

Government published in September 2018. To support research funding of the BMWi, the Federal Ministry of Education and Research (BMBF) funds projects on the topic of reactor safety within the framework of the funding guideline “Richtlinie zur Förderung von Zuwendungen im Rahmen des 7. Energieforschungsprogramms der Bundesregierung in der Nuklearen Sicherheitsforschung und der Strahlenforschung” (guideline on the funding of grants under the 7th Energy Research Programme of the Federal Government in nuclear safety research and radiation research). Furthermore, the institutional financing of the activities of the Helmholtz-Gemeinschaft (HGF) in the field of nuclear safety research within the Helmholtz programme “NUSAFE” is the responsibility of the BMBF.

The research work funded by the Federal Government within the framework of the 7th Energy Research Programme deal i.a. with experimental or analytical studies on

- realistic, detailed descriptions of the processes in the reactor core, in the cooling cycles and in the containment during power and decommissioning operations as well as during incidents and accidents, identifying measures to contain even serious incidents,
- material-science investigations on structural materials, components and materials, especially on ageing and integrity, methods for material characterisation and non-destructive testing,
- methods of structural analysis for assessing the integrity of building structures and components,
- safety-relevant impacts of human activities and organisation,
- probabilistic methods for improving tools that identify vulnerabilities in the power plant design and processes management, and
- safety issues relating to innovative safety systems and digital control systems.

Computer codes developed as part of BMWi-funded projects are available to the supervisory authorities and their authorised experts for analyses of the safety of nuclear installations.

The licence holders (VGB) of nuclear facilities also continue to give high priority to research and development in the field of nuclear safety. Due to the decision to phase out the use of nuclear energy for the commercial generation of electricity by 2022, the licence holders focus their efforts on the operation of the nuclear installations still in operation as well as on decommissioning and dismantling. There are currently around 80 ongoing projects, and new projects are added each year with a total volume of orders of around 5 million euros (status: September 2018). The annual projects focus on the following topics:

- materials engineering,
- safety assessment,
- thermohydraulics, core design,
- civil engineering, seismic design,
- electrical and I&C engineering, incl. qualification of components,
- operational databases,
- standards, legal questions, and
- others.

Activities of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

In fulfilling its statutory tasks for the safe use of nuclear energy, the BMU has to clarify questions of fundamental importance for the safety of nuclear installations (→ Article 8).

The BMU keeps continuously up to date with the developments in the field of nuclear safety by taking an active part in the work of international committees and working groups (IAEA, OECD/NEA, committees resulting from bilateral and multilateral agreements and treaties, etc.). The results of the work of these committees and working groups as well as of the research programmes and research and development projects funded by the Federal Government at national level are used for the continuous improvement of the requirements for the safety of the nuclear installations in accordance with the state of the art in science and technology. The BMU also requests its advisory commissions RSK, ESK and SSK (Commission on Radiological Protection) (→ Article 8) to comment on selected developments or events in the field of nuclear safety and to formulate recommendations. The expert organisation Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH supports the BMU and carries out research projects on the safety of nuclear installations from a generic point of view on behalf of the BMU. GRS evaluates events that have occurred in German but also foreign nuclear installations with regard to their safety significance and applicability to other installations and prepares recommendations in the form of information notices (WLNs).

Position of the Federal Republic of Germany on the safety of the nuclear installations in Germany

With the entry into force of the 13th AtG amendment, the decision taken by the Federal Government to end the use of nuclear energy for the commercial generation of electricity in the Federal Republic of Germany by the end of 2022 at the latest was implemented. Independently of the decision to phase out nuclear power, the Federal Government is expressly committed to maintaining or improving the high level of nuclear safety of the German nuclear installations. Major elements in ensuring safety are the licence holders' responsibility for the safety of the nuclear installations as well as comprehensive supervision by the competent nuclear licensing and supervisory authorities.

The Federal Government ascertains that the Federal Republic of Germany fulfils the obligations under the Convention on Nuclear Safety.

Progress and changes since the year 2017

Besides the permanent nuclear supervision of the nuclear installations, § 19a AtG demands a ten-yearly Safety Review of the nuclear installations in power operation, which has been carried out for all nuclear installations in power operation. Owing to the shutdown of further nuclear installations in accordance with the 13th AtG amendment in 2011 and due to the fact that the AtG demands Safety Reviews to be carried out only up to three years before shutdown, it is expected that the two Safety Reviews carried out at the nuclear installations Gundremmingen, Unit C and Brokdorf were the last Safety Reviews carried out in Germany. Both reviews have been completed and the final reports have been submitted to the responsible *Land* authorities for review.

Implementation of the "Vienna Declaration on Nuclear Safety"

In the "Vienna Declaration on Nuclear Safety" (February 2015), additional provisions were specified in order to achieve the aims of the Convention – the prevention of accidents with radiological consequences and, if possible, the mitigations of the possible effects of accidents.

Germany complies with all the principles of the "Vienna Declaration on Nuclear Safety". This is reported on in Articles 14, 18 and 19.

Table 6-2 Accident management measures implemented in PWRs before 2011

Measure	Construction line 3				Construction line 4		
	KKG	KWG	KKP 2	KBR	KKI 2	KKE	GKN II
Emergency manual (NHB)	●	●	●	●	●	●	●
Secondary-side bleed	●	●	●	●	●	■	■
Secondary-side feed	●	●	●	●	●	●	●
Primary-side bleed	●	●	●	●	●	●	●
Primary-side feed	●	●	■	●	●	■	■
Containment isolation	●	■	●	●	●	■	■
Filtered containment venting	●	●	●	●	●	●	●
Passive autocatalytic recombiners	●	●	●	●	●	●	●
Filtering of control room air	●	●	●	●	●	■	●
Emergency power supply by neighbouring unit	□	□	●	□	□	□	●
Sufficient battery capacity	●	■	●	●	●	●	●
Re-establishment of external electrical energy supply	●	●	●	●	●	●	■
3rd grid connection (underground cable)	●	●	●	●	●	●	●
Containment sampling system	●	●	●	●	●	●	●

● Realised through backfitting ■ Design □ Not applicable

GKN: Kernkraftwerk Neckarwestheim
KBR: Kernkraftwerk Brokdorf
KKE: Kernkraftwerk Emsland
KKG: Kernkraftwerk Grafenrheinfeld
KKI 2: Kernkraftwerk Isar Block 2
KKP 2: Kernkraftwerk Philippsburg Block 2
KWG: Kernkraftwerk Grohnde

Table 6-3 Accident management measures implemented in BWRs before 2011

Measure	SWR 72	
	KRB II B	KRB II C
Emergency manual (NHB)	●	●
Diverse emergency HPCI system (steam-driven pump)	□	□
Additional RPV injection and makeup system	●	●
Containment isolation	■	■
Diverse RPV pressure limitation	●	●
Filtered venting	●	●
Inerting of containment with nitrogen	●*	●*
Filtering of control room air	●	●
Emergency power supply by neighbouring unit	●	●
Increase of battery capacity	■	■
Re-establishment of external electrical energy supply	●	●
3rd grid connection (underground cable)	●	●
Containment sampling system	●	●

● Realised through backfitting ■ Design □ Not applicable

* Pressure suppression pool inerted, drywell and pressure suppression pool with passive autocatalytic recombiners (PARs)

KRB II B: Kernkraftwerk Gundremmingen Block B

KRB II C: Kernkraftwerk Gundremmingen Block C

Future activities

In accordance with the AtG, the nuclear installations in power operation will be definitively shut down by the following dates at the latest:

- Philippsburg Unit 2 31 December 2019
- Grohnde 31 December 2021
- Gundremmingen Unit C 31 December 2021
- Brokdorf 31 December 2021
- Isar Unit 2 31 December 2022
- Emsland 31 December 2022
- Neckarwestheim Unit II 31 December 2022

7 Legislative and regulatory framework

ARTICLE 7 LEGISLATIVE AND REGULATORY FRAMEWORK

1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.
2. The legislative and regulatory framework shall provide for:
   i) the establishment of applicable national safety requirements and regulations;
   ii) a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence;
   iii) a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;
   iv) the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.

7 (1) Legislative and regulatory framework

The system of regulation under nuclear and radiation protection law in Germany

The aim of the nuclear and radiation protection licensing and supervisory authorities of the Federation and the *Länder* is to monitor whether the licence holders of all nuclear installations and facilities in Germany ensure the required safety.

A system of checks and balances is in place between the Federation and the *Länder* in the context of a distribution of tasks (federal executive administration, i.e. execution by the *Länder* on federal commission). This system, which has existed for many decades, is based on trust and control between the Federation and the *Länder* and forms the basis for the continued existence of high safety requirements. To simplify matters, the term “nuclear” licensing and supervisory authorities of the Federation and/or the Länder (i.e. under nuclear law) is used in the following even if the respective authority is usually also the licensing and supervisory authority under radiation protection law.

In Germany, the independence of regulatory decision-making at both federal and *Länder* level is ensured by a clear functional separation.

Constitutional framework

Incorporation of international and European law

Germany is a republic with a federal structure and is composed of 16 federal states (in German called *Länder*). This structure is laid down in the Basic Law of the Federal Republic of Germany (Grundgesetz (GG)). Together with the nuclear and radiation protection law, the GG forms the framework for the use of nuclear energy in the Federal Republic of Germany.

The Federal Chancellor determines the competence of the supreme federal authorities by organisational decree. The responsibility for the nuclear safety of nuclear installations and radiation protection was thus transferred to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The GG has assigned the legislative power for the peaceful use of nuclear energy to the Federation. As part of the Federal Government, the BMU is involved in legislation, in particular by drafting legislation, while the *Länder* implement the Atomic Energy Act on behalf of the Federation (federal executive administration).

International treaties

In the hierarchy of rules and legislation, the international treaties concluded by the Federal Republic of Germany in accordance with Article 59(2) sentence 1 GG are on the same level as formal federal laws. For the Federal Republic of Germany, the Convention on Nuclear Safety entered into force on 20 April 1997. As a matter of principle, rights and obligations under the treaty only apply to the Federal Republic of Germany as contracting party.

Law of the European Atomic Energy Community and the European Union (EU)

In Germany, legislation and administrative work must take into account any binding requirement from regulations of the European Atomic Energy Community (Euratom) and the EU.

According to Article 77 of the Euratom Treaty, the use of ores, source materials and special fissile materials for the peaceful use of nuclear energy is subject to the control regime of the Euratom.

Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom entered into force on 6 February 2014. It fundamentally revised European radiation protection law and merged it into a single directive. The deadline for transposing Directive 2013/59/Euratom into national law ended on 6 February 2018. The obligation of transposition was taken as an opportunity to reorganise and modernise German radiation protection law. In particular, a formal law was passed to protect against the harmful effects of ionising radiation (Radiation Protection Act (StrlSchG)).

On 22 July 2009, Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations entered into force. Thus, for the first time, legally binding European regulations had been established in the field of nuclear safety. The objective of the Directive is to maintain and continuously improve nuclear safety. The EU member states shall provide for appropriate national arrangements to effectively protect workers and the general public against the dangers arising from ionising radiation from nuclear installations. The directive applies, among others, to nuclear installations, research reactors and storage facilities but not to disposal facilities for radioactive waste. The Directive includes provisions regarding the establishment of a legislative and regulatory framework for nuclear safety, the organisation and tasks of the nuclear licensing and supervisory authorities, the obligations of the licence holders of nuclear installations, the education and training of the staff of all parties involved, and on information to the public. The Directive maintains the national responsibility for nuclear safety among others by the fact that the member states explicitly have the right to take more stringent safety measures in addition to the provisions of the Directive in compliance with Community law (Article 2(2) of the Directive). Directive 2009/71/Euratom was transposed into national law with the 12th AtG amendment[7].

With Directive 2014/87/Euratom, Directive 2009/71/Euratom was amended. By this amendment, for the first time, general technical requirements for nuclear safety in Europe are laid down at a legally binding level, in particular the implementation of the defence-in-depth concept and clear allocation of responsibilities for on-site emergency response. Furthermore, the member states are obliged to conduct – in addition to the decennial self-assessment of the national legislative, regulatory and organisational framework and the competent nuclear licensing and supervisory authorities (so-called "peer review") already contained in Directive 2009/71/Euratom – topical peer reviews on a safety issue jointly to be selected by the member states at least every six years, starting in 2017. This is to initiate a continuous system of mutual learning from each other. Directive 2014/87/Euratom was transposed into national law with the entry into force of the 15th AtG amendment on 9 June 2017.

[7] 12th Act amending the Atomic Energy Act, Federal Law Gazette, 8 December 2010

7 (2i) Nuclear legal and regulatory framework

National nuclear legal and regulatory framework

The "Handbook on Nuclear Safety and Radiation Protection" contains all legal and substatutory regulations applicable in Germany for the following areas:

- nuclear safety,
- disposal,
- transport of radioactive materials, and
- protection against ionising and non-ionising radiation.

The "Handbook on Nuclear Safety and Radiation Protection" is available at https://www.bfe.bund.de/DE/bfe/gesetze-regelungen/rsh/rsh_node.html.

Figure 7-1 presents the hierarchy of the national regulations, the authority or institution issuing them and their degree of bindingness.

Acts, ordinances and administrative provisions

Basic Law (GG)

The GG contains provisions on the competences of the Federation and the *Länder* with regard to the use of nuclear energy. According to Article 73 No. 14 GG, the Federation has exclusive legislative power in this area. The *Länder* predominantly execute nuclear and radiation protection law relevant for the use of nuclear energy (with the exception of the provisions of the off-site emergency management system of the Federation and the *Länder*) on behalf of the Federation (federal executive administration). Here, the Federation exercises legal and expediency oversight and may, if it deems it necessary, assume the competence for the subject matter. In any case, the *Länder* remain responsible for any administrative action towards external parties (competence to exercise duties). Tasks in the field of radioactive waste management are largely carried out by direct federal administration in accordance with § 23d AtG.

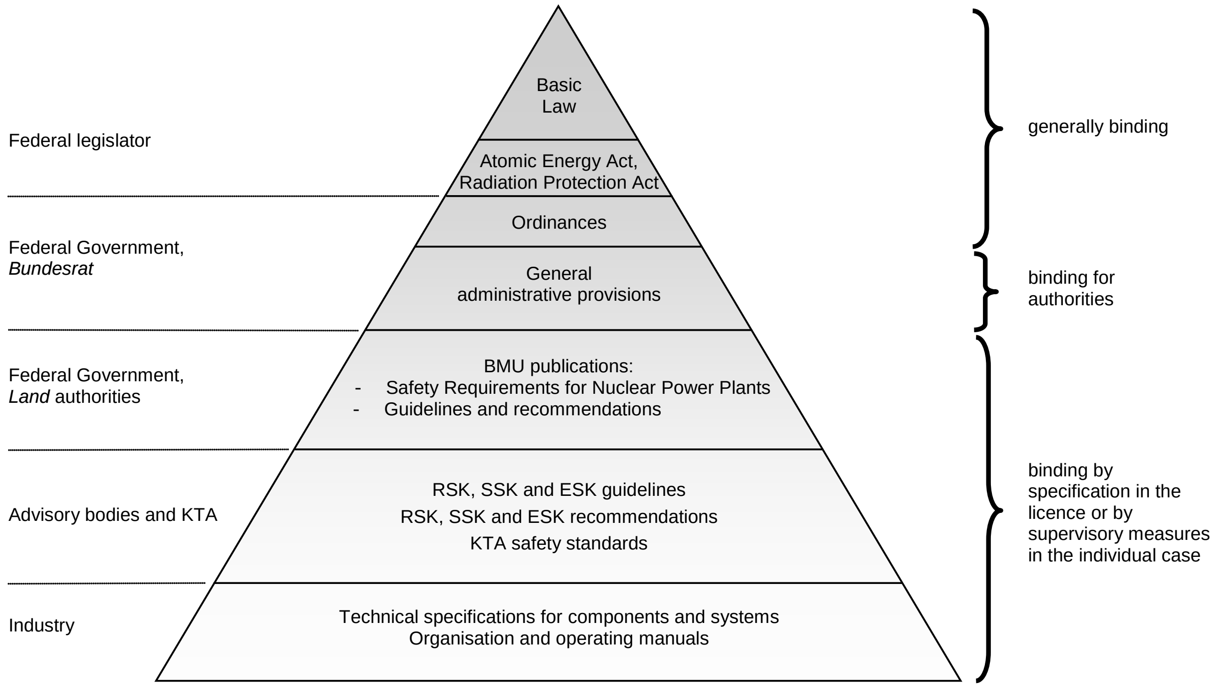

Figure 7-1 National regulatory pyramid

Formal federal law, in particular the Atomic Energy Act (AtG) and Radiation Protection Act (StrlSchG)

Atomic Energy Act

The AtG includes the general national regulations for protective and preventive measures and the disposal of radioactive waste and spent fuel in Germany and is the basis for the associated ordinances.

The AtG was promulgated on 23 December 1959 and has since then been amended several times. The purpose of the AtG after the amendment in 2002 is

- to phase out the use of nuclear energy for the commercial generation of electricity in a controlled and structured manner and, until then, to ensure orderly operation of the nuclear installations,
- to protect life, health and real assets against the hazards of nuclear energy and the harmful effects of ionising radiation and to provide compensation for any damage caused. According to § 7(2) AtG, precautions shall be taken to prevent damage resulting from the construction and operation of the nuclear installations. For this purpose, the state of the art in science and technology is defined as the benchmark for granting a licence.
- to prevent danger to the internal or external security of the Federal Republic of Germany from the use of nuclear energy,
- to ensure that the Federal Republic of Germany meets its international obligations in the field of nuclear energy and radiation protection.

On 30 June 2011, the *Bundestag* (German Federal Parliament) passed the 13th AtG amendment, which, in response to the reactor accident at the Fukushima Daiichi nuclear power plant, provides for phasing out the commercial use of nuclear energy at the earliest possible date on a step-by step basis by 31 December 2022 at the latest. The amended AtG entered into force on 6 August 2011. Constitutional complaints were lodged with the Federal Constitutional Court against the 13th AtG amendment. On 6 December 2016, the Federal Constitutional Court issued its ruling on these constitutional complaints, according to which the provisions are essentially in conformity with the constitution. The minor constitutional deficits identified by the Federal Constitutional Court were eliminated by the 16th AtG amendment of 10 July 2018.

Further to purpose and general provisions, the AtG also comprises surveillance regulations, general regulations on responsibilities of the administrative authorities, liability provisions as well as provisions on the payment of fines.

To protect against the hazards arising from radioactive substances and to control their utilisation, the AtG requires that the construction and operation of nuclear installations is subject to regulatory licensing. The AtG regulates, in particular,

- prerequisites and procedures for the granting of licences,
- performance of supervision,
- consultation of authorised experts, and
- charging of procedural costs.

However, the regulations stipulated therein are not exhaustive and are further substantiated regarding procedures and substantive legal requirements by ordinances and other substatutory regulations. According to § 7 AtG, a licence is required for the construction, operation or any other holding of a stationary installation for the production, treatment, processing or fission of nuclear fuel as well as for essentially modifying such installation or its operation.

Radiation Protection Act (StrlSchG)

With the implementation of Directive 2013/59/Euratom, legislation on radiation protection was reorganised and modernised. The Act on the Protection against the Harmful Effects of Ionising Radiation (StrlSchG), which was enacted as Article 1 of the Act on the Reorganisation of the Law on the Protection against the Harmful Effects of Ionising Radiation of 27 June 2017, regulates radiation protection for the first time in a formal statute. Most of the provisions of the StrlSchG entered into force on 31 December 2018. The provisions of the StrlSchG on radiological emergency preparedness and response and monitoring of environmental radioactivity, which replace the Precautionary Radiation Protection Act formerly in force, as well as the authorisations to issue statutory instruments have been in force since 1 October 2017.

The StrlSchG regulates, among other things,

- radiation protection principles and limits,
- the operational organisation of radiation protection,
- the emergency management system of the Federation and the *Länder*, and
- the protection of emergency workers.

Another legal basis is the “Act on the Establishment of a Federal Office for Radiation Protection”, by which this office is assigned certain tasks in the field of radiation protection, including emergency preparedness and response, to support the nuclear licensing and supervisory authority (regulatory authority) of the Federation.

The “Act on the Establishment of a Federal Office for the Safety of Nuclear Waste Management” of 2013 created the basis for the establishment of the Federal Office for the Safety of Nuclear Waste Management (BfE). With this Act, the BfE is entrusted with regulatory, licensing and supervisory tasks of the Federation in the field of disposal, storage as well as for the handling and transport of high-level radioactive wastes as well as administrative tasks in the field of nuclear safety. In order to fulfil its tasks, the BfE conducts scientific research in these fields.

Ordinances

For further specification of the legal regulations, the AtG (see listing in § 54(1) AtG) and the StrlSchG include authorisations for issuing ordinances. Relevant ordinances are issued by the Federal Government, but they require the consent of the *Bundesrat* (German Federal Council). The *Bundesrat* is a constitutional body of the Federation in which the governments of the *Länder* are represented. The applicable ordinances on protective and preventive measures for nuclear installations are listed in Table 7-1.

On 31 December 2018, the Ordinance on Protection against the Harmful Effects of Ionising Radiation (Radiation Protection Ordinance (StrlSchV)), based in particular on authorisations to issue ordinances under the StrlSchG, entered into force. The new StrlSchV is Article 1 of the Ordinance for the Further Modernisation of Radiation Protection Law of the Federal Government of 29 November 2018. The new StrlSchV contains provisions which supplement and concretise the provisions of the StrlSchG. The contents of the X-ray Ordinance formerly in force have been incorporated into the StrlSchG and the new StrlSchV. The StrlSchG and the new StrlSchV together ensure comprehensive protection against the harmful effects of ionising radiation. The previous StrlSchV and X-ray Ordinance expired on 31 December 2018.

The Emergency Dose Level Ordinance came into force on 31 December 2018 as a further ordinance to modernise radiation protection law. It specifies dose levels which in the case of a radiological emergency serve as radiological criteria for the appropriateness of the most important early measures for the protection of the population (stay in buildings, request to take iodine tablets, evacuation).

Table 7-1 Ordinances on protective and preventive measures for nuclear installations

Brief description on the legislative content	
StrlSchV	**Radiation Protection Ordinance** Including occupational radiation protection, protection of the public, exemption levels, clearance of radioactive material, requirements for dose determination, reporting and notification obligations
AtVfV	**Nuclear Licensing Procedure Ordinance** Application documents (one safety analysis report), public participation, safety specifications (operational limits and conditions for safe operation), procedures and criteria for major modifications
AtSMV	**Nuclear Safety Officer and Reporting Ordinance** Position, duties, responsibilities of the nuclear safety officer, reporting of special events in nuclear installations according to § 7 AtG
AtZüV	**Nuclear Trustworthiness Verification Ordinance** Verification of trustworthiness of persons to protect against diversion or major release of radioactive material
AtDeckV	**Nuclear Financial Security Ordinance** Financial security pursuant to the AtG
AtSKostV	**Cost Ordinance under the Atomic Energy Act and the Radiation Protection Act** Charging of costs in nuclear and radiation protection procedures
KIV	**Ordinance Concerning Potassium Iodide Tablets** Provision and distribution of medicine containing potassium iodide as thyroid blocker in case of radiological events
AtAV	**Nuclear Waste Transfer Ordinance** Transfer of radioactive wastes into or out of the territory of the Federal Republic of Germany
NDWV	**Emergency Dose Level Ordinance** Definition of dose levels for early emergency response measures
IMIS-ZustV	**IMIS Competence Ordinance** Responsibilities of federal authorities in the Integrated Measurement and Information System for the Monitoring of Environmental Radiation (IMIS) pursuant to the StrlSchG
EndlagerVlV	**Repository Prepayment Ordinance** Advance payments for the construction of federal facilities for the long-term engineered storage and disposal of radioactive waste

General administrative provisions

According to Articles 84 to 86 of the Basic Law, the Federal Government may issue general administrative provisions for the execution of the laws and ordinances on nuclear and radiation protection by federal and *Land* authorities. If execution is thereby regulated by the *Länder*, Articles 84(2) and Article 85(2) sentence 1 GG stipulate that this is subject to the consent of the Bundesrat. General administrative provisions regulate the actions of the authorities, thus only being directly binding for the administration. However, they have an indirect effect if serving as a basis for concrete administrative decisions. General administrative regulations relevant for the field of nuclear safety are listed in the "Handbook on Nuclear Safety and Radiation Protection".

Documents provisionally considered as federal emergency plans

According to the new provisions of §§ 97 to 99 StrlSchG, the Federal Government is to issue a general federal emergency plan for emergency preparedness within the meaning of Article 16 of the Convention on Nuclear Safety on the basis of the proposals by the BMU. For all administrative and economic sectors in which appropriate protective measures are to be taken in the event of an emergency, this general emergency plan shall be supplemented and substantiated by special federal emergency plans based on the proposals by the competent federal ministries. The Federal Government shall adopt the federal emergency plans in the form general administrative provisions with the consent of the *Bundesrat*.

According to a transitional provision, the corresponding stipulations and descriptions in general administrative provisions, SSK recommendations and other planning documents referred to in Annex 4 of the StrlSchG shall provisionally be regarded as federal emergency plans until these new federal emergency plans or the ordinances on emergency preparedness provided for in the StrlSchG have been adopted. The corresponding stipulations and descriptions of the documents listed in Table 16-2 of this report are therefore to be observed by the competent authorities in their decisions on protective measures in the event of an emergency until the adoption of the new emergency plans of the Federal Government in accordance with the provisions of the StrlSchG.

Review and amendment of the emergency plans

According to § 103 StrlSchG, emergency plans of the Federation and the *Länder* are regularly reviewed and, if necessary, amended in the light of experience gained from emergency exercises, lessons learned from emergencies in Germany or abroad as well as changes in the state of scientific knowledge and the legal situation.

Regulatory guidelines published by the BMU

After having consulted the *Länder*, the BMU publishes regulatory guidelines in the form of requirements, guidelines, criteria and recommendations. In general, these are regulations passed in consensus with the competent licensing and supervisory authorities of the *Länder* on the uniform application of the nuclear and radiation protection law.

The publications of the BMU describe the view of the nuclear licensing and supervisory authority of the Federation and, if the decisions were taken in the *Länder* Committee for Nuclear Energy (LAA), also the view of the nuclear licensing and supervisory authorities of the *Länder* on general issues (nuclear safety, radiation protection, emergency preparedness) and administrative practice and serve as orientation for the nuclear licensing and supervisory authorities of the *Länder* in the execution of the nuclear and radiation protection law. They are referred to by the competent nuclear licensing and supervisory authorities of the *Länder* in the course of licensing procedures or supervisory actions under their own responsibility. This also ensures that the execution of nuclear and radiation protection law in the different *Länder* takes place according to comparable standards as far as possible. In relation to the licence holders of the nuclear installations, these regulatory guidelines become binding by taking them into account in nuclear licences or orders of the nuclear supervisory body.

The most important substatutory nuclear regulations are the “Safety Requirements for Nuclear Power Plants”, including their “Interpretations”. These contain fundamental and overriding safety requirements within the framework of the substatutory regulations which serve to specify the necessary precaution in line with the state of the art of science and technology to prevent damage caused by the construction and operation of nuclear installations pursuant to § 7(2)3 AtG. With regard to the nuclear installations operated in Germany, this concerns modification procedures. An update of the “Safety Requirements for Nuclear Power Plants” was published on 30 March 2015. The announcement of the BMU specifies in what context these are to be applied by the *Länder*. As far as necessary from a safety-related point of view, the “Safety Requirements for Nuclear Power Plants” shall also apply to nuclear installations that pursuant to § 7(1a) AtG have had their power operating licences revoked or which due to a decision taken by the licence holder are in their post-operational phase.

Currently, there are more than 100 regulatory guidelines in the field of nuclear safety. These are regulations pertaining to the following:

- “Safety Requirements for Nuclear Power Plants”,
- accident management measures to be planned by the licence holders with regard to postulated design extension conditions,
- measures regarding disaster control in the vicinity of nuclear installations,
- measures against disruptive action or other interference by third parties,
- radiation protection during maintenance work,
- reporting criteria for reportable events at nuclear installations and research reactors,
- monitoring of emissions and radioactivity in the environment,
- the periodic Safety Review for nuclear installations,
- technical documents to be prepared regarding construction, operation and decommissioning of nuclear installations,
- documents to be supplied with the application for a licence,
- procedures for the preparation and performance of maintenance and modification work in nuclear installations, and
- personnel qualification.

Other regulations on the safety of nuclear installations

KTA safety standards

The safety standards of the Nuclear Safety Standards Commission (KTA safety standards) specify, among other things, the safety requirements of the general regulations (“Safety Requirements for Nuclear Power Plants” and their “Interpretations”) and put them into concrete terms.

The Nuclear Safety Standards Commission (KTA) is formed at the BMU. According to § 2 of its statutes, it has the task to ensure the establishment of safety standards in fields of nuclear technology where consensus is emerging between experts of the manufacturers and licence holders of nuclear installations and of authorised experts and the authorities, and to support their application.

The KTA is composed of seven expert members from each of the following groups:

- manufacturers and builders of nuclear installations,
- licence holders of nuclear installations,
- the *Land* authorities responsible for executing the AtG in the case of nuclear installations and the federal authority responsible for exercising supervision in accordance with Articles 85 and 87c of the Basic Law,
- consultants and consultancy organisations, and
- other authorities, organisations and bodies concerned with nuclear technology.

The KTA is governed by an Executive Committee consisting of one member and one deputy each from the groups of manufacturers, licence holders, authorities and authorised experts. The members of the Executive Committee elect a chairperson from among their number.

Managing the affairs of the KTA is the responsibility of an office set up at the BfE. This office is led by a managing director in accordance with the technical instructions given by the Executive Committee.

The safety standards of the KTA are drafted by experts in subcommittees and special working bodies and adopted by the KTA. The five groups are equally represented in the KTA with seven out of a total of 35 votes each. A safety standard will only be adopted if five sixth of the members give their approval. Thus, no group voting unanimously can be outvoted.

The KTA safety standards are part of the substatutory regulations and are not legally binding per se. Their function is to specify the general requirements for precautions against damage as are necessary in the light of the state of the art in science and technology for their scope of application. Due to their development process, they are legally classified as anticipating expert opinions and thus have a legally binding effect. If the requirements of the KTA safety standard are complied with, the damage precautions as are necessary in the light of the state of the art in science and technology have generally also been taken.

Historically, the KTA safety standards developed on the basis of applicable national nuclear rules and regulations and American nuclear safety standards. For example, the ASME Code (American Society of Mechanical Engineers Code) (Section III) was the model for the design and calculation of components.

The KTA safety standards relate to

- organisational issues and occupational health and safety (specific additions in the field of nuclear safety),
- plant and structural engineering,
- operation,
- electrical and I&C systems,
- mechanical components,
- reactor core and system design, and
- radiological protection.

Quality assurance and quality management play an important role. This aspect is addressed in most of the safety standards. The quality assurance concept of the KTA safety standards also includes the field of ageing, which is internationally treated as a separate issue today. There are also separate KTA safety standards for management systems and ageing management.

The KTA programme of standards currently comprises 97 standards. Of these, 88 safety standards will remain applicable after 2022, nine are no longer part of the revision process. Currently, six of the 97 standards are in the revision process.

The regulatory power of the legislator and administrative action by the competent nuclear licensing and supervisory authorities are not restricted by the KTA process.

Recommendations of the Reactor Safety Commission (RSK), the Nuclear Waste Management Commission (ESK) or the Commission on Radiological Protection (SSK)

The BMU requests its commissions (RSK, ESK and SSK) (→ Article 8) for advice on important issues related to licensing and supervisory procedures for nuclear installations in operation, shut down or under decommissioning, the development of rules and regulations or safety research. In addition, the commissions may also give advice on their own initiative. Depending on the issue at hand, the nuclear licensing and supervisory authorities of the *Länder*, experts, the licence holders of nuclear installations or the industry are also involved in the consultations. The consultation results of the commissions are statements or recommendations, published by the commissions themselves on their websites after approval by the BMU. The nuclear licensing and supervisory authorities of the *Länder* review the decisions (recommendations and opinions) of the commissions on their own responsibility in the nuclear licensing and supervisory procedures, in particular with regard to plant-specific relevance. They decide whether, and if so, what action is required in the particular case and initiate any necessary measures.

Conventional technical standards

For the construction and operation of nuclear installations, conventional technical standards apply as a supplement. This is particularly the case for the national standards of the German Institute for Standardization (DIN) as well as the international standards of ISO and IEC (International Electrotechnical Commission).

In this respect, the requirements of the conventional technical standards are to be referred to as a minimum standard for nuclear systems and components. Moreover, provisions of the Federation and the *Länder* relating to nuclear law shall not be affected to the extent that other or more stringent requirements are made or permitted by them.

Updating nuclear rules and regulations

The “Safety Requirements for Nuclear Power Plants” and their “Interpretations” are subjected to reviews at regular intervals, at the latest every five years. Necessary amendments are jointly adopted in the LAA by the BMU and the nuclear licensing and supervisory authorities of the *Länder* and then published by the BMU.

The KTA safety standards are subject to regular reviews. In accordance with the statutes, the texts of the adopted safety standards are reviewed at least every five years and, where required, adapted to the state of the art in science and technology in terms of the necessary precautions to prevent damage. Until the end of 2017, all KTA safety standards were reviewed again in order to achieve validity in accordance with the statutes until at least the end of 2022 (termination of power operation of the last nuclear installations in Germany).

In September 2014, the Western European Nuclear Regulators Association (WENRA) published a revised version of the “WENRA Safety Reference Levels”. These consider the lessons learned from the reactor accident in Fukushima. Germany carried out a self-assessment on the extent to which the revised “Safety Reference Levels” are contained in the national nuclear rules and regulations. It was found that, in general, there are no gaps in the national nuclear rules and regulations and in supervisory practice and that only selective adjustments to the national nuclear rules and regulations were carried out in the review period (2017 – 2019). Concrete modification proposals were elaborated together with the nuclear licensing and supervisory authorities of the *Länder*, adopted in the LAA and published by the BMU.

Germany closely follows the development of the IAEA safety standards. Newly published IAEA safety standards are compared with the German regulations. During the review period, this did not result in any indications for the need to update the German regulations.

Development of international rules and regulations

With the technical experts from nuclear licensing and supervisory authorities and expert organisations, Germany continues to participate in the further development of the international nuclear rules and regulations, e.g. by the secondment of German experts to prepare and revise the IAEA general safety requirements and the IAEA safety standards. Furthermore, staff members of the BMU and BfE are members of the following bodies of the IAEA:

- CSS (Commission on Safety Standards)
- NUSSC (Nuclear Safety Standards Committee)
- WASSC (Waste Safety Standards Committee)
- RASSC (Radiation Safety Standards Committee)

- TRANSSC (Transport Safety Standards Committee)
- EPreSSC (Emergency Preparedness Safety Standard Committee)

Germany is thus making an active contribution to the international harmonisation of safety requirements. Since 2006, the IAEA's rule-making activities have been summarised in an annual BMU report provided to the nuclear licensing and supervisory authorities of the *Länder*, their authorised experts and the general public. A comparison of the national nuclear rules and regulations with the current IAEA safety standards was also prepared and is continually updated.

In addition, Germany is a member of WENRA and its working groups, in particular the RHWG (Reactor Harmonization Working Group), is actively involved in the development of the WENRA Safety Reference Levels and Safety Objectives and thus contributes to the harmonisation of nuclear safety at the European level.

7 (2ii) Licensing system

General provisions

The granting of a licence for nuclear installations is regulated in the AtG. According to § 7 AtG, a licence is required for the construction and operation of stationary installations for the production, treatment, processing and fission of nuclear fuel or for the reprocessing of spent nuclear fuel. Essential modifications of nuclear installations or their operation as well as the decommissioning of an installation also require a licence from the competent nuclear licensing and supervisory authority. When issuing a licence, obligations may generally be imposed for meeting the protective purpose.

According to § 7(1) sentence 2 AtG, no further licences will be issued for the construction and operation of installations for the fission of nuclear fuel for commercial generation of electricity or of facilities for the reprocessing of spent nuclear fuel. However, the operating licences already granted are not limited in time and do not require any extension or renewal. The authorisation to operate the existing nuclear installations shall expire once the electricity volume for that installation as specified in the AtG or the electricity volume derived from transfers has been produced, but not later than the date specified for each nuclear installation (§ 7(1a) AtG). Accordingly, for nuclear installations, nuclear licensing procedures are only performed for essential modifications (§ 7(1) AtG) and their decommissioning (§ 7(3) AtG).

Thus, the following presentation concentrates on licensing procedures for essential modifications of the existing nuclear installations or their operation. Decommissioning of nuclear installations is the subject of reporting within the framework of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

The planned modifications of a nuclear installation or its operation are to be assessed systematically with regard to their impacts on the necessary protective and preventive measures. As stipulated in § 7(1) AtG, essential modifications of nuclear installations or their operation are subject to licensing. For modifications requiring a licence, the fulfilment of the licensing prerequisites is to be verified according to § 7(2) AtG. Accordingly, a licence may only be granted if

- there are no known facts giving rise to doubts as to the reliability of the applicant and of the persons responsible for the construction and management of the installation and the supervision of its operation, and the persons responsible for the construction and management of the installation and the supervision of its operation have the requisite qualification,
- it is assured that the persons who are otherwise engaged in the operation of the installation have the necessary knowledge concerning the safe operation of the installation, the possible hazards and the protective measures to be taken,

- the precautions have been taken as are necessary in the light of the state of the art of science and technology to prevent damage resulting from the construction and operation of the installation,
- the necessary financial security has been provided to comply with the legal liability to pay compensation for damage,
- the necessary protection has been provided against disruptive action or other interference by third parties, and
- the choice of the site of the installation does not conflict with overriding public interests, in particular in view of its environmental impacts.

Modifications of nuclear installations or their operation that are not essential do not require a licence. However, they are to be reported to the nuclear supervisory authority within the framework of nuclear supervision and may be subject to accompanying inspections by the nuclear supervisory authority. Specifications for modification procedures are in place in the written operating procedures of the licence holders.

The actual details and procedure of licensing according to the AtG are regulated more detailed in the AtVfV.

Nuclear licensing procedures

Licence application

The written licence application is submitted to the competent licensing and supervisory authority of that *Land* in which the nuclear installation is sited. The applicant has to submit all documents required for the examination of the licensing prerequisites by the nuclear licensing and supervisory authority and the experts consulted by it. These documents are listed in detail in § 2 and § 3 AtVfV and their form further specified in guidelines.

In the case of applications for modification licences, the examination of the licensing prerequisites does not only refer to the object of modification. In addition, also those plant components and procedural steps of the licensed plant will be examined on which the modification will have an impact. The documents submitted by the applicant must cover these plant components and procedural steps. In order to verify that the licensing prerequisites are fulfilled, appropriate documents are to be submitted on the issues concerned by the modification. Moreover, a safety analysis report is to be submitted (§ 3(1)1 AtVfV), which is reviewed by the competent nuclear licensing and supervisory authority with the support of authorised experts in the course of the licensing procedure.

In addition to the safety analysis report, the applicant also has to submit the following to the nuclear licensing and supervisory authority:

- supplementary plans, drawings and descriptions of the installation and its components,
- information concerning measures provided for the installation and its operation against interference and other intervention by third parties, according to § 7(2)5 AtG,
- information enabling the examination of the reliability and expertise of the persons responsible for the construction of the installation and the management and supervision of its operation,
- information enabling a verification as to whether the persons otherwise engaged in the operation of the installation possess the necessary knowledge in accordance with § 7(2)2 AtG,
- a schedule containing all the data relevant for the safety of the installation and its operation, the measures to be taken in the event of incidents or damage, and an outline plan of the tests provided for safety-related components of the installation (safety specifications),

- proposals for financial security to cover the legal liability to pay compensation,
- a description of the radioactive residues accumulating as well as data concerning the measures provided for the prevention of any accumulation of radioactive residues, for the safe utilisation of accumulated radioactive residues and dismantled or dismounted radioactive components of the installation in accordance with the purposes referred to in § 1 nos. 2 to 4 AtG, for the disposal of radioactive residues or dismounted radioactive components in a controlled and structured manner in the form of radioactive wastes, including their intended treatment, as well as for the anticipated storage of radioactive wastes until their disposal, and
- information on other environmental impacts of the project which are required for the examination pursuant to § 7(2)6 AtG with respect to approval decisions which, in individual cases, may be included in the licensing decision, or for decisions to be taken by the nuclear licensing and supervisory authority in accordance with provisions relating to the conservation of nature and the maintenance of landscapes; the requirements for the content of the information are determined by the relevant legal provisions for the above-mentioned decisions.

Examination of the application

On the basis of the submitted documents, the nuclear licensing and supervisory authority assesses whether or not the licensing prerequisites have been met. All federal, *Land*, local and other regional authorities and, according to circumstances also authorities of other states (§ 7a AtVfV), whose jurisdiction is involved shall take part in the licensing procedure. For the assessment of safety issues, it is common practice to engage technical safety organisations to support the nuclear licensing and supervisory authority in the evaluation of the application documents. In written safety evaluation reports, the authorised experts explain whether or not the requirements regarding nuclear safety and radiation protection have been met. They have no autonomous decision-making powers. The nuclear licensing and supervisory authority assesses and decides on the basis of its own judgement. In making its decisions, it is not bound by the opinions of the authorised experts. Further information on consulting authorised experts is given in the explanations on Article 8.

Within the frame of federal executive administration, the nuclear licensing and supervisory authority of the *Land* informs the BMU if it considers the licensing procedure to be significant, or if the BMU issued requirements within the framework of federal oversight (e.g. for power increases applied for). Information is also given if the BMU deems it necessary to involve the Federation in the individual case.

In performing these safety-related tasks within federal oversight, the BMU consults its advisory commissions (RSK, ESK and SSK) and in many cases the expert organisation Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH for advice and technical support. Where required, the BMU states its position on the draft decision to the nuclear licensing and supervisory authority of the *Land*.

Environmental impact assessment (EIA)

The requirement to conduct an EIA for nuclear installations is regulated in the Act on the Assessment of Environmental Impacts (UVPG) in conjunction with § 2a AtG. The EIA is carried out as a dependent part of the approval procedure for the nuclear installation or its modification. For projects requiring an EIA, the applicant has to enclose an EIA report with his application (§ 3(2) AtVfV). This report must describe, among other things, the measures and features of the project which are intended to exclude, reduce or offset the occurrence of any potential substantial adverse environmental impacts of the project as well as the environmental impacts of the project to be expected. Not only the radiological consequences for the environment are considered but also the other impacts caused by the construction, operation or decommissioning of the installation (e.g. impacts on the natural balance, the water balance, noise, light, land consumption, etc.). The public and authorities affected in their area of responsibility can comment on the EIA report, but also on other application documents (§ 7(1) AtVfV and § 7(4)1 AtG) such as the safety analysis report (§ 6(1)2 in conjunction with § 3(1)1 AtVfV).

Subsequently, the competent nuclear licensing and supervisory authority prepares a summary description of the environmental impacts (§ 14a(1) AtVfV) and carries out an assessment of the environmental impacts to be taken into account in the decision on the admissibility of the project with regard to effective environmental protection (§ 14a(2) AtVfV).

Public participation

The purpose of public participation is to enable the citizens to bring in their interests directly into the procedure. Participation of the public was mandatory for construction licences and is mandatory for the first decommissioning licence. In the case of essential modifications, the authority may foresee public participation if the modification will have no adverse effects on the public. However, the public has to be involved if this is required pursuant to the UVPG. The AtVfV includes detailed regulations on

- the conditions under which the nuclear licensing and supervisory authority may foresee public participation or must involve the public,
- the public announcement of the project and public disclosure of the application documents at a suitable location near the site for a period of two months, including the request for raising any objections within the presentation period (§§ 4 to 7a AtVfV), and
- holding a public hearing where the objections are discussed between nuclear licensing and supervisory authority, licence applicant and those who have raised the objections (§§ 8 to 13 AtVfV).

The nuclear licensing and supervisory authority considers and evaluates the objections from public participation in its decision-making and states the reasons for the decision.

If the licensing procedure is conducted with public participation, the applicant shall submit a brief, readily comprehensible description of the installation and the modification applied for for informing the public in addition to the application documents to be submitted in all licensing procedures for examination of the licensing prerequisites by the nuclear licensing and supervisory authority and the authorised experts (§ 6(1)3 in conjunction with § 3(4) AtVfV). In addition to public participation in the licensing procedure, the laws of the *Länder* generally provide for public participation at an early stage during which the project implementer informs the public about the project already before application and provides the opportunity for comments and discussions.

Licensing decision

The final decision of the nuclear licensing and supervisory authority is based on the entirety of application documents, safety evaluation reports by the authorised experts and, if available, the statement by the BMU and the authorities involved as well as the findings from objections raised in the public hearing. Prerequisite for the legality of the decision is that all procedural requirements of the AtVfV are fulfilled. The decision of the nuclear licensing and supervisory authority can be appealed before administrative courts.

The AtG includes the necessary authorisation providing the basis for the licensing and supervisory authorities of the *Länder* to take action against an unlicensed construction or unlicensed operation of a nuclear installation. In particular, the nuclear licensing and supervisory authority is empowered to temporarily prohibit an unlicensed construction or mode of operation by an immediately enforceable order of discontinuance or to order final cessation of operation. This applies if a required licence had not been granted by the nuclear licensing and supervisory authority or if the required licence had been revoked. The nuclear licensing and supervisory authority does not only have these powers in cases where a nuclear installation is operated without any licence, but also if the installation has been constructed or is operated materially differently from the licences granted.

7 (2iii) Regulatory inspection and assessment (supervision)

After the necessary licence has been granted, nuclear installations are subject to continuous regulatory supervision in accordance with the AtG and associated ordinances over their entire lifetime from the start of construction to the end of decommissioning. This supervision is performed by the nuclear licensing and supervisory authorities of the *Länder* on behalf of the Federation. Just as in the licensing procedure, the *Länder* are assisted by independent authorised experts. The decisions on supervisory measures to be performed are taken by the nuclear licensing and supervisory authority. As in licensing, the supreme objective of regulatory supervision of nuclear installations is to protect the general public and the people working in these installations against the risks associated with the operation of the installation. On-site supervisory activities of the nuclear licensing and supervisory authority are performed, on average, once per week and installation. The representatives of the supervisory and licensing authorities have unrestricted access to the installations.

The nuclear licensing and supervisory authority pays particular attention to

- the fulfilment of the requirements of the AtG, the StrlSchG, the ordinances issued under the AtG and the StrlSchG and the other nuclear safety standards and guidelines,
- the fulfilment of the provisions, obligations and ancillary provisions imposed in the licence notices, and
- the fulfilment of any supervisory order.

To ensure safety, the nuclear licensing and supervisory authority monitors, also with the help of the authorised experts or by other authorities,

- compliance with the safety-relevant operating procedures,
- the performance of in-service inspections of safety-relevant components and systems,
- the evaluation of reportable events,
- the implementation of modifications of the nuclear installation or its operation,
- radiation protection monitoring of personnel in nuclear installations,
- radiation protection monitoring in the vicinity of the nuclear installation, including the operation of the remote monitoring system for nuclear power plants (KFÜ), being independent from the licence holder,
- compliance with the plant-specific authorised limits for radioactive discharges,
- the measures taken against disturbers or other interference by third parties,
- the reliability of the licence holder,
- the technical qualification and the maintenance of the qualification of the responsible persons as well as of the knowledge of personnel otherwise engaged in the installation, and
- the quality assurance measures.

The involvement of the different management levels of the licence holder is always ensured. During plant revisions with refuelling outages and after reportable events, on-site supervision also takes place every working day or permanently.

The authorised experts consulted by the nuclear licensing and supervisory authority are more frequently on site, have access to the installation at all times in accordance with the AtG and are authorised to perform necessary examinations and to demand pertinent information (§ 20 in conjunction with § 19(2) AtG). The nuclear licensing and supervisory authority is not bound by the result of the examinations.

The licence holders of the nuclear installations have to submit written operating reports to the nuclear licensing and supervisory authorities at regular intervals. These include data on the operating history, on maintenance measures and inspections, on radiation protection and on radioactive waste material. Any radiologically and safety-relevant events must be reported to the nuclear licensing and supervisory authorities according to the provisions specified in the AtSMV. The regulations and procedures regarding reportable events and their evaluation are described in the explanations on Article 19 (iv) to (vii). In addition, the licence holders regularly report on specific issues.

In addition to the continuous regulatory supervision, comprehensive periodic Safety Reviews are performed every ten years. Since 2002, the obligations to conduct the Safety Reviews and to submit the results on specified dates are also regulated by law in § 19a AtG (→ Article 14 (i)).

7 (2iv) Enforcement of regulations and provisions

Enforcement by regulatory order, particularly in urgent cases

According to § 19 AtG, the nuclear licensing and supervisory authority may order that the licence holder discontinues a situation which is contrary to the provisions of the AtG, the ordinances issued under the AtG, the terms and conditions of the licence or to any subsequently imposed obligation, or which may constitute a hazard to life, health or property due to the effects of ionising radiation. Depending on the specific circumstances of the individual case, it may, in particular, order that,

- specific protective measures shall be taken,
- radioactive material shall be stored or kept in custody at a place designated by it, and
- the handling of radioactive material, the construction and operation of installations of the kind referred to in § 7 AtG shall be suspended or, if a requisite licence has not been granted or definitely revoked, discontinued.

The powers of the nuclear licensing and supervisory authority in case of an unlicensed mode of operation are dealt with in Article 7 (2ii).

In case of non-fulfilment of the licensing provisions or supervisory orders, the nuclear licensing and supervisory authority of the respective *Land* is authorised to enforce their fulfilment by coercive administrative measures in accordance with the general provisions.

Enforcement by modification or revocation of the licence

Under certain conditions, stipulated in § 17 AtG, obligations for ensuring safety may be decreed by the nuclear licensing authority even after a licence has been granted. In case a considerable hazard is suspected from the nuclear installation endangering the persons engaged at the installation or the general public which cannot be removed within a reasonable time by appropriate measures, then the nuclear licensing authority must revoke the issued licence. A revocation is also possible if prerequisites for the licence permit cease to be met at a later time or if the licence holder violates legal regulations or decisions by the authorities.

Prosecution of violations of nuclear law provisions

The Criminal Code (StGB), the AtG and the nuclear ordinances provide for sanctions to prosecute violations.

Criminal offences

Any violation that must be considered as a criminal offence is dealt with in the StGB. Whosoever, e.g.,

- operates, otherwise holds, modifies or decommissions a nuclear installation without the required licence (§ 327 StGB),
- constructs a defective nuclear installation (§ 312 StGB),
- handles nuclear fuel without the required licence (§ 328 StGB),
- releases ionising radiation or causes nuclear fission processes capable of damaging life and limb of another person (§ 311 StGB), and
- procures or manufactures nuclear fuel, radioactive materials or other equipment for himself in preparation of certain criminal offences (§ 310 StGB)

shall be liable to imprisonment or a fine.

Administrative offences

§ 46 AtG, § 194 StrlSchG and the associated ordinances deal with administrative offences and which are sanctioned by the imposition of fines on the acting persons. An administrative offence is committed by any person, e.g., who

- erects installations for the fission of nuclear fuel without a licence, or
- acts in violation of a regulatory order or obligation imposed.

In case of administrative offences, fines of up to 50,000 euros may be imposed on a person committing such an offence. A legally effective fine imposed may put in question the personal reliability that was a prerequisite for the licence and may therefore require the replacement of the responsible person.

Experiences

Due to the intense regulatory supervision (→ Article 7 (2iii)) of the design, construction, commissioning, operation and decommissioning of nuclear installations, in Germany, inadmissible conditions are generally detected at an early stage and their elimination demanded and enforced before the legally possible actions, such as imposed obligations, orders, administrative offence procedures and criminal proceedings, are taken.

The instruments presented have proven their effectiveness since, in the normal case, they ensure that the nuclear licensing and supervisory authorities have appropriate sanction possibilities and powers for the enforcement of regulations and provisions, if required.

8 Regulatory Body

ARTICLE 8 REGULATORY BODY

1. Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.
2. Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.

8 (1) Authorities, committees and organisations

Composition of the regulatory body

Germany is a republic with a federal structure and is composed of 16 federal states, referred to as the *Länder*. Unless otherwise specified, the execution of federal laws generally lies within the responsibility of the *Länder*. The “regulatory body” is therefore composed of the nuclear licensing and supervisory authorities of the Federation and the *Länder* (→ Figure 8-1).

By organisational decree, the Chancellor designates the federal ministry competent for nuclear safety and radiation protection. This competence and thus the responsibility for organisation, staffing and material resources of the nuclear licensing and supervisory authority of the Federation lies with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The necessary human and financial resources are applied for by the BMU from the annual federal budget.

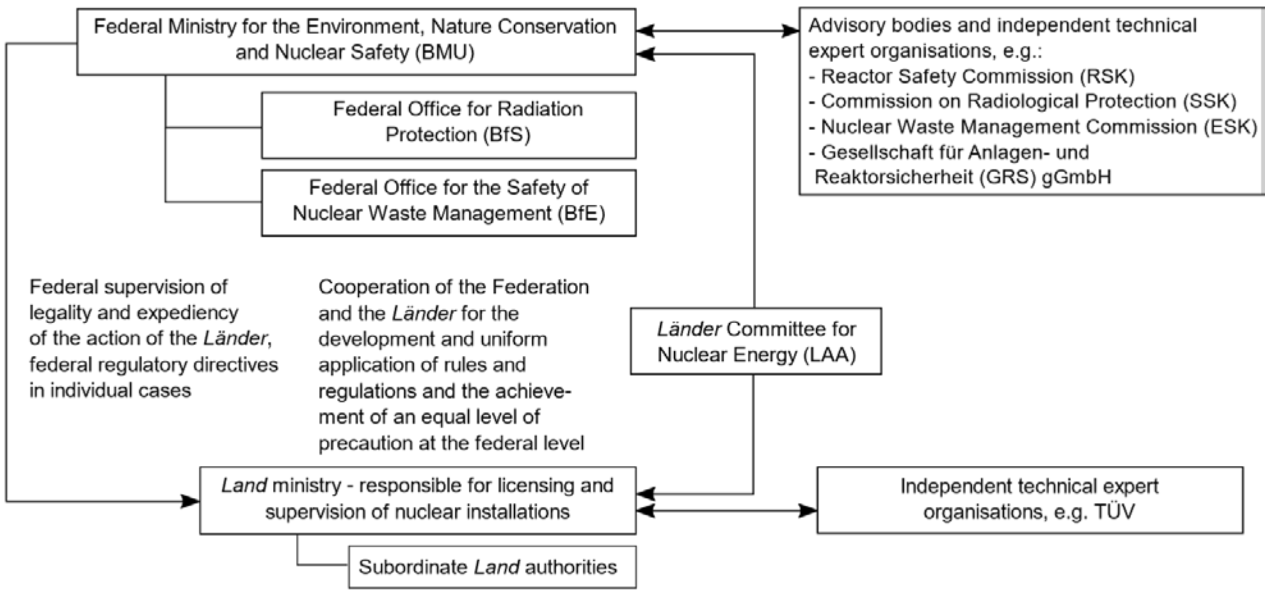

Figure 8-1 Structure of the regulatory body

Regarding the obligations under the Convention on Nuclear Safety, the BMU carries overall state responsibility towards the interior of Germany as well as towards the international community. It ensures that those in charge of the applicants and licence holders, federal and *Land* authorities and of the technical safety organisations ensure effective protection of man and the environment against the hazards of nuclear energy and the harmful effects of ionising radiation at any time.

According to § 24 of the Atomic Energy Act (AtG), the respective governments of the *Länder* designate the supreme *Land* authorities (*Land* ministries) responsible for nuclear licensing and supervision. Hence, the responsibility for organisation, staffing and material resources of these executive authorities lies solely with the respective governments of the *Länder*. In individual cases, subordinate authorities may also be tasked with supervisory functions. Further regulations are in place for the responsibilities of the Federal Office for Radiation Protection (BfS) in § 185 StrlSchG and the Federal Office for the Safety of Nuclear Waste Management (BfE) in § 23d AtG.

Assignment of competencies of the regulatory body

Responsibilities in the Federation and in the Länder

Competent federal authorities

In addition to responsibility for the nuclear safety of nuclear installations and radiation protection, the BMU is also responsible for the organisation, staffing and resources of the nuclear licensing and supervisory authority of the Federation.

Directorate-General S “Nuclear Safety, Radiological Protection” (→ Figure 8-3) of the BMU comprises three directorates. Directorate S I performs tasks in the field of nuclear safety. Directorate S II performs radiation protection tasks, including off-site emergency preparedness and response. Directorate S III deals with tasks relating to nuclear waste management. With regard to the tasks of the BfE, S III carries out legal and technical supervision. It is also stated in the Strategic Plan for Directorate-General S that the BMU bears nationwide governmental responsibility for the effective protection of people, the environment and assets from nuclear hazards and risks as well as from harmful effects of ionising and non-ionising radiation. Aware of this responsibility, a high safety culture is to be maintained and further developed.

Competent nuclear licensing and supervisory authorities of the Länder

In the AtG, the supreme *Land* authorities have been designated as competent nuclear licensing and supervisory authorities.

Analogous to the federal level, there is also an effective separation at the *Länder* level between the tasks of the nuclear licensing and supervisory authority and the competent authority for economic development. This ensures the effective independence of the nuclear licensing and supervisory authorities from the operators of nuclear installations and facilities in decision-making processes.

Within the framework of decisions on licences, the nuclear licensing and supervisory authorities of the *Länder* examine the fulfilment of the licensing requirements. The concrete form and implementation of the licensing procedure under the AtG are regulated in detail in the Nuclear Licensing Procedure Ordinance (Atomrechtliche Verfahrensverordnung (AtVfV)).

Within the framework of supervision, the respective *Land* nuclear authority monitors, with the assistance of authorised experts, in particular,

- compliance with the provisions of the AtG, the StrlSchG, the ordinances under nuclear and radiation protection law and other nuclear safety standards and guidelines,
- compliance with the provisions, obligations and ancillary provisions imposed in the licence, and
- fulfilment of supervisory orders issued.

In addition, the *Land* nuclear authority also monitors, with the assistance of authorised experts or through other authorities, among other things,

- performance of in-service inspections and maintenance measures for safety-relevant components,
- the evaluation of special occurrences and the development and implementation of appropriate measures against recurrence,
- the implementation of non-essential modifications to the installation or its operation,
- radiation protection monitoring of personnel in nuclear installations,
- the measures taken by the licence holder for environmental monitoring of nuclear installations,
- compliance with the plant-specific authorised limits for the discharge of radioactive substances via air and water,
- the measures against disruptive action or other interference by third parties,
- the reliability of the applicant,
- the technical qualification and the maintenance of qualification of the responsible persons as well as of the knowledge of personnel otherwise engaged in the installation, and
- the quality assurance measures.

Distribution of responsibilities between the Federation and the *Länder*

The distribution of responsibilities between the Federation and the *Länder* provides for the licensing and supervisory authorities of the *Länder* to take administrative action on their own responsibility. The *Länder* thus have the competence for the subject matter and remain responsible for the administrative action with external effect.

Thus, in practice, the *Länder* carry out the tasks assigned to them on their own responsibility. However, the Federation has the right to issue directives within the framework of federal executive administration. The Federation only makes use of this option only in exceptional, individual cases as a last resort. Before this happens, the BMU strives to clarify differing views through consultations. This can usually be achieved. If, however, an agreement is not possible, the Federation can instruct the *Länder* to take concrete administrative action or prescribe a decision (instruction). In doing so, it takes over the competence in the subject matter.

Communication with the licence holder, which includes any legally binding action, is exclusively performed by the *Länder* (competence to execute duties).

The essential processes of nuclear supervision of the Federation and the *Länder* as well as their interfaces in connection with the safety of nuclear installations in power operation and in post-operation are described in a "Handbook on Cooperation between the Federation and the *Länder* in Nuclear Law" (Supervision Manual). The essential tasks of the Federal Government and the *Länder* are described in Table 8-2.

In the case of facilities for the safekeeping and disposal of radioactive waste, state supervision is regulated differently. The nuclear waste management sector was reorganised in order to efficiently select a site for a disposal facility for high-level radioactive waste. For this purpose, the BfE was established in 2014 as the central licensing and supervisory authority in the field of waste management.

The responsibility for performance and implementation of the tasks described above primarily lies with the BMU and the competent nuclear licensing and supervisor authorities of the *Länder*. According to Article 7 (2ii) to (2iv), this regulatory body consisting of federal and *Land* authorities has to fulfil four basic functions:

- development of safety requirements and regulations,
- implementation of licensing procedures,
- regulatory review and assessment (supervision), and
- enforcement of rules.

From the articles of the Convention listed below, further functions are derived that are to be fulfilled by the relevant competent regulatory body:

- regulatory safety research (→ Articles 14, 18, 19),
- system for the application of operating experience (→ Article 19),
- radiation protection (→ Article 15),
- emergency preparedness (→ Article 16), and
- international cooperation (Preamble vii and viii, Article 1).

Table 8-1 shows the competent nuclear licensing and supervisory authorities of the *Länder* in which nuclear installations in terms of the Convention are located.

As a matter of principle, the licensing and supervisory authorities of the Federation and the *Länder* are involved in all regulatory functions, albeit with different competencies, responsibilities and duties to cooperate. This distribution is shown in Table 8-2. Further details are provided in the relevant articles of this report.

Common understanding of regulatory nuclear supervision

The BMU and the nuclear licensing and supervisory authorities of the *Länder* have prepared a joint Handbook on Cooperation between the Federation and the *Länder* in Nuclear Law (Supervision Manual), which illustrates the cooperation between the Federation and the *Länder* in the case of power reactors with operating licences and the cooperation between the Federation and the *Länder* in nuclear procedures. The Supervision Manual adopted by the *Länder* Committee for Nuclear Energy (LAA) describes the core processes of the supervision of nuclear installations (power operation and post-operation) and the interfaces between the nuclear supervision of the Federation and the *Länder*. The Supervision Manual serves as a common basis for action and cooperation for the nuclear licensing and supervisory authorities of the Federation and the *Länder* and was last updated in June 2018.

Table 8-1 Competent nuclear licensing and supervisory authorities of the *Länder* with nuclear installations

<table>
<tr><th>Land</th><th>Nuclear installation</th><th>Licensing authority</th><th>Supervisory authority</th></tr>
<tr><td>Baden-Württemberg</td><td>Neckarwestheim I
Neckarwestheim II
Philippsburg 1
Philippsburg 2</td><td>Ministry of the Environment, Climate Protection and the Energy Sector of Baden-Württemberg in agreement with the Interior Ministry of Baden-Württemberg</td><td>Ministry of the Environment, Climate Protection and the Energy Sector of Baden-Württemberg</td></tr>
<tr><td>Bavaria</td><td>Isar 1
Isar 2
Grafenrheinfeld
Gundremmingen B
Gundremmingen C</td><td colspan="2">Bavarian State Ministry of the Environment and Consumer Protection</td></tr>
<tr><td>Hesse</td><td>Biblis A
Biblis B</td><td colspan="2">Hessian Ministry of the Environment, Climate Protection, Agriculture and Consumer Protection</td></tr>
<tr><td>Lower Saxony</td><td>Unterweser
Grohnde
Emsland</td><td colspan="2">Lower Saxony Ministry for the Environment, Energy, Construction and Climate Protection</td></tr>
<tr><td>Schleswig-Holstein</td><td>Brunsbüttel
Krümmel
Brokdorf</td><td colspan="2">Ministry of Energy Transition, Agriculture, the Environment, Nature and Digitisation Schleswig Holstein</td></tr>
</table>

Table 8-2 Assignment of the regulatory functions to the nuclear licensing and supervisory authorities of the Federation and the *Länder*

Regulatory function	Tasks and competencies of the regulatory body	
	Authority of the Federation	**Authorities of the *Länder***
Main functions		
Establishment of national safety requirements and regulations [Art. 7 (2i)]	Further development of the legal regulations (decision by the *Bundestag* in the case of formal statutes, by Federal Government with approval of the *Bundesrat* in the case of ordinances) and the national nuclear rules and regulations	Participation on the basis of consolidated findings and needs in connection with execution; supplementary administrative procedures of the respective *Länder*
Licensing system for nuclear installations [Art. 7 (2ii)]	Supervision of legality and expediency* Checking of consolidated findings with regard to their relevance for standard national requirements	Checking of applications and notifications according to § 7 AtG, granting of licences and approvals
System of regulatory inspection and assessment of nuclear installations [Art. 7 (2iii)]		Controls and inspections in the nuclear installations, checking and assessment with regard to the relevance for the safety of the nuclear installation as well as for protective and preventive measures
Enforcement of applicable regulations and of the terms of licences [Art. 7 (2iv)]		Implementation of necessary measures to avert hazards and for necessary safety improvements as well as improvement of protective and preventive measures
Secondary functions		
Regulatory safety research	Investigation of safety issues for standard requirements	Plant-specific studies
Monitoring of events, operating experience and implementation	Examination and assessment of events in Germany and abroad with regard to relevance for the safety of the nuclear installations as well as to protective and preventive measures, national organisation of experience feedback	Examination and assessment of events with regard to relevance for the safety of the nuclear installations as well as for protective and preventive measures
Radiation protection, environmental monitoring	Monitoring of exposure of the population and the federal territory	Plant-specific monitoring of emissions and immissions (exposure of workers and in the environment)
Emergency preparedness	Ordinances with radiological criteria for protective measures; federal emergency plans; federal radiological situation centre (radiological situation report, cross-national emergency preparedness, international reporting systems, national and international coordination)	Participation in the preparation of the ordinances and emergency plans of the Federation, preparation of own emergency plans which supplement and concretise the general and special emergency plans of the Federation; plant-related disaster control (including external emergency plans for nuclear installations)
International cooperation	Participation in international activities to determine the state of the art in science and technology and regarding the national nuclear rules and regulations, and provision for national purposes Fulfilment of international obligations; assertion of German safety interests	Consideration of the internationally documented state of the art in science and technology Participation in the cooperation with neighbouring countries in the case of nuclear installations in border regions, especially on the basis of bilateral agreements

grey	Leading function, execution within the area of competence
light grey	Function with separate competences but common objectives
white	“Federalism function”, supervision with regard to legality and expediency or participation
*	This also means that the Federation may execute its power to decide on the merits of the case itself and initiate the related detailed examinations on its own authority.

Subordinate authorities in the *Länder*

Since the responsibility for nuclear licensing and supervision is assigned to the supreme authorities of the *Länder* (ministries), only a few tasks are fulfilled by subordinate authorities of the *Länder*, e.g. the remote monitoring system for nuclear power plants (Kernkraftwerks-Fernüberwachungssystem (KFÜ)).

Cooperation of the authorities of the Federation and the *Länder* (regulatory body) – *Länder* Committee for Nuclear Energy (LAA)

In the federal German system, in which the tasks are shared between the Federation and the *Länder*, the coordination of tasks and joint action to increase nuclear safety has a very special role to play. To this end, the Federation and the *Länder* founded the LAA already in 1958. The LAA is a permanent federal and *Länder* body composed of representatives of the nuclear licensing and supervisory authorities of the *Länder* and of the BMU. It supports the Federation and the *Länder* in the execution of the Atomic Energy Act (AtG) and the Radiation Protection Act (StrlSchG) as well as in the preparation of amendments and the further development of legal and administrative provisions and of the substatutory rules and regulations. In particular, the LAA serves the mutual communication and exchange between the nuclear licensing and supervisory authorities of the Federation and the *Länder* as well as the coordination of activities. In the interest of a nationwide uniform enforcement of nuclear and radiation protection law, the competent nuclear licensing and supervisory authorities of the *Länder* and the Federation develop, in consensus, respective regulations. These are announced by the BMU in the Federal Gazette. The BMU chairs the LAA and manages its affairs. The Committee's decisions are usually made by mutual consent. The LAA (→ Figure 8-2) has four technical committees for issues related to legal matters, nuclear safety, radiation protection as well as fuel cycle matters. Working groups for special tasks are assigned to the technical committees. If required, the technical committees may set up ad hoc working groups for special issues. The technical committees and the permanent working groups usually convene twice a year and more frequently if necessary. The General Committee convenes once a year. The discussions in the LAA are an important instrument for the early and full involvement of the *Länder* and supplement the right of the *Länder* of participation in the legislative procedure of the *Bundesrat*.

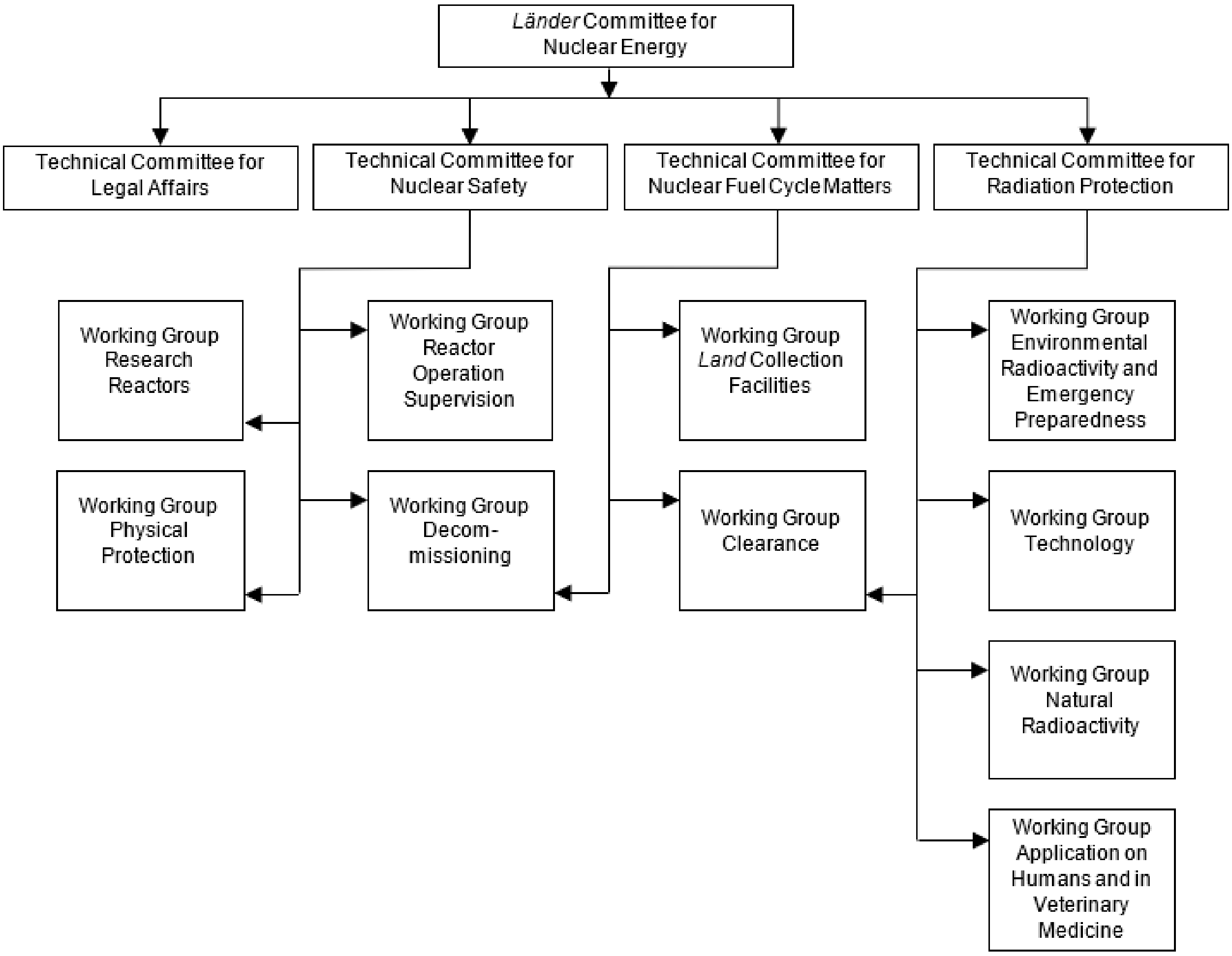

Figure 8-2 Structure of the *Länder* Committee for Nuclear Energy (LAA)

Organisation and staffing of the authorities of the Federation and the *Länder*

Nuclear regulatory authorities of the Federation

The nuclear regulatory authority of the Federation is the BMU. Directorate-General S “Nuclear Safety, Radiological Protection” of the BMU comprises three directorates. These, in turn, comprise work units (working groups, divisions). Figure 8-3 shows the structure of Directorate-General S with the three directorates and their work units.

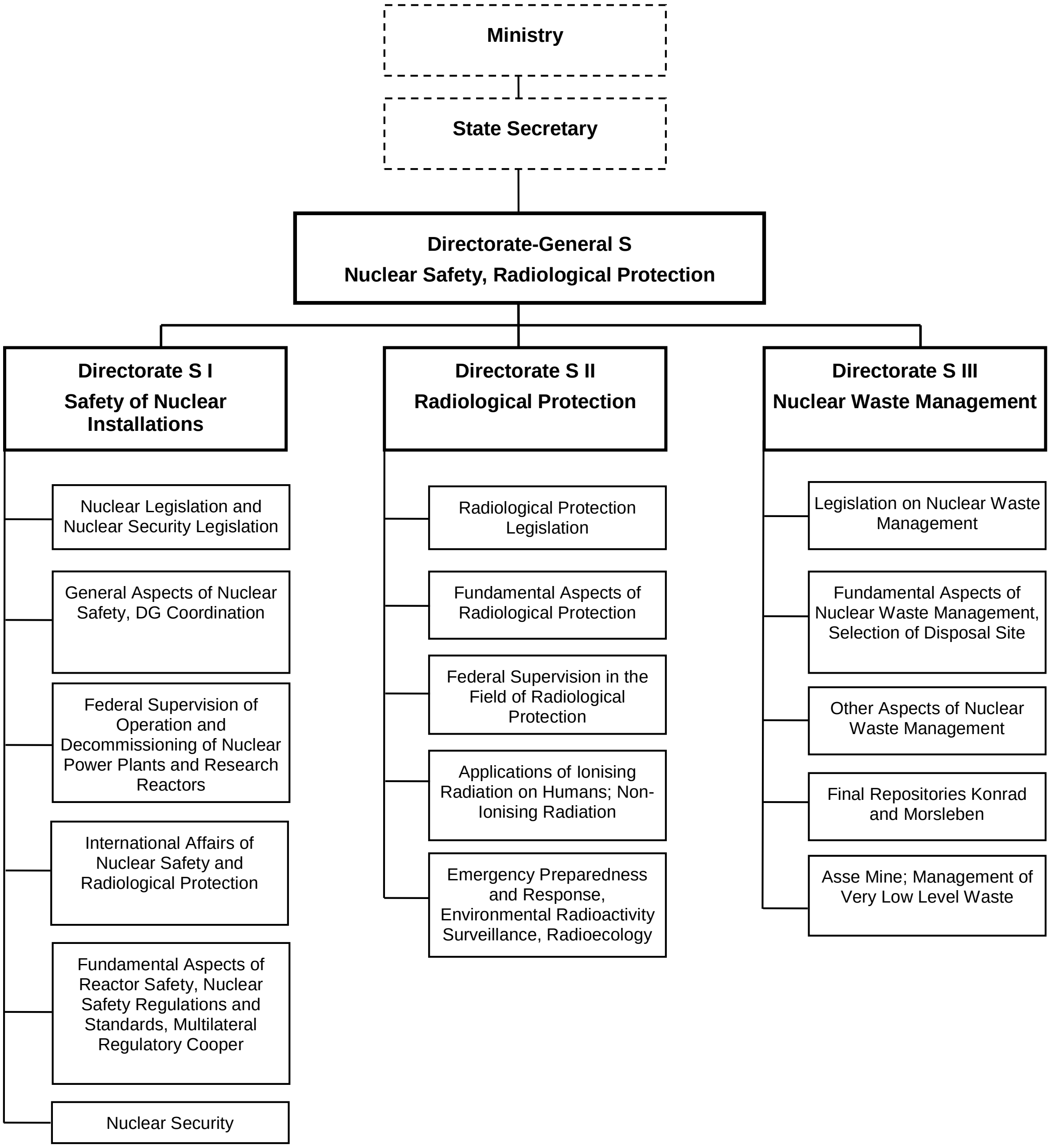

Figure 8-3 Organisation of Directorate-General S at the BMU

Staffing of the BMU

The staff of the BMU is composed of civil servants appointed for life and public service employees.

The legal civil servants or public sector workers are required to have qualified at university and to have passed the corresponding examinations. The scientific-technical civil servants of Directorate-General S are required to have completed university studies with a Master’s degree (senior service) or studies at a university of applied sciences or university studies completed with a Bachelor’s degree (higher service). Apart from that, there are no relevant regulations on training and qualification.

At the BMU, the responsibility for fulfilling the obligations under the Convention on Nuclear Safety primarily lies with Directorate S I. The staffing of Directorate S I (permanent positions) with legal experts (including higher-service staff of other non-technical disciplines) and with scientific and technical experts of higher and senior service is shown in Figure 8-4.

Directorate S I
Safety of Nuclear Installations
1 legal staff, 1 administrative staff

	S I 1 Nuclear Legislation	S I 2 Coordination	S I 3 Federal Supervision	S I 4 International Affairs	S I 5 Fundamental Aspects	S I 6 Nuclear Security
Legal experts	5	2	-	1	-	1
Scientific and technical experts	-	-	10	5	8	7

Figure 8-4 Organisation and staffing of Directorate S I

In Directorate S II "Radiological Protection", another 18 employees are entrusted with tasks that are related to the Convention, e.g. with radiation protection in nuclear installations or emergency preparedness and response.

Staffing of the BfE

The BfE as a regulatory authority in the field of waste management is currently being established. The tasks in terms of the Convention are performed in Directorate-General "Nuclear Safety and Supervision in Nuclear Waste Management" by approximately 30 staff members.

Nuclear licensing and supervisory authorities of the *Länder*

The nuclear licensing and supervisory authorities of the *Länder* for the supervision of nuclear facilities are the ministries (supreme *Land* authorities) determined by the *Land* governments. Table 8-1 shows the ministries competent for nuclear installations in terms of the Convention. Within the ministries, the tasks of the nuclear licensing and supervisory authority are usually fulfilled by ministerial directorates. The structure of such directorates depends on the kind and scope of the nuclear activities and installations in the individual *Land*. These directorates are in turn subdivided into divisions for the execution of the licensing and supervisory procedures for the nuclear installations and are supported, where necessary, by additional divisions dealing with radiation protection and environmental radioactivity, waste management, fundamental issues and legal affairs. In some *Länder*, nuclear fuel cycle facilities not pertaining to the scope of the Convention have to be supervised in addition to nuclear installations and research reactors.

The directorate for the supervision of nuclear facilities is usually supported by a further organisational unit of the ministry which is, in many cases, a directorate for central tasks (e.g. human resources and budgetary affairs, infrastructure tasks and general services). For illustration purposes, Figure 8-5 shows the basic organisation of a *Land* ministry directorate for the supervision of nuclear installations.

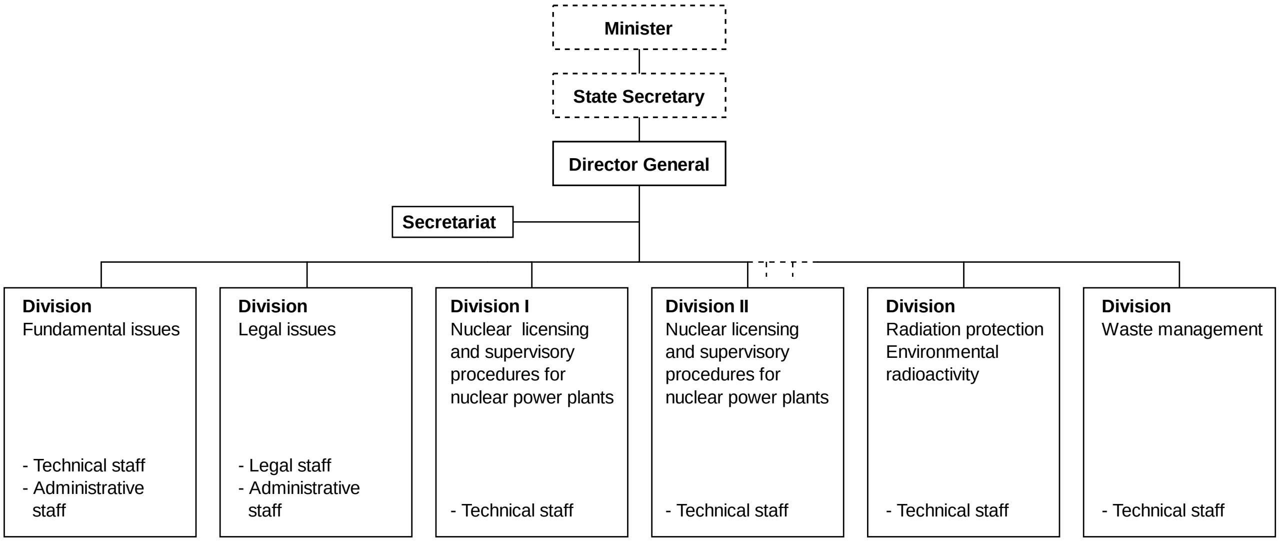

Figure 8-5 Basic organisation of a *Land* ministry directorate for the supervision of nuclear installations

Staffing of the *Länder*

The directorates for the supervision of nuclear installations mainly employ scientific and technical specialist staff, especially engineers and scientists. They also have legal experts and administrative staff, to some extent also industrial psychologists. All these directorates carry out reviews and assessments as well as tasks related to the execution of the nuclear licensing and supervisory procedure as described more detailed in the following articles. There is no strict allocation of staff to the tasks of review and assessment, licensing or to inspection.

When recruiting new staff and in connection with further qualification, the nuclear licensing and supervisory authorities take care that they have their own expert personnel in the specialist fields that are important for nuclear safety. Furthermore, the staff is tasked with the management and assignment of the authorised experts consulted as well as with the review and assessment of authorised experts' statements.

Regarding the staffing of the nuclear licensing and supervisory authorities of the *Länder*, it has to be taken into account that according to § 20 AtG authorised experts may be consulted in the nuclear administrative procedure. The nuclear licensing and supervisory authorities of the *Länder* make use of this option regularly and extensively due to the large extent of the inspections and the associated wide range of different scientific and technical disciplines required as well as the special technical equipment needed. To carry out the nuclear licensing and supervisory procedures, about 30 to 40 persons are required for one single nuclear installation per year. This includes the work of the authority staff and of the authorised experts consulted.

Competence of the regulatory body staff

Already in its previous reports under the Convention on Nuclear Safety, the Federal Government always affirmed that efficient and competent nuclear licensing and supervision is necessary for the remaining period of operation of the nuclear installations and during their decommissioning. To ensure this, the authorities responsible in Germany guarantee the necessary financial resources, the technical competence of their staff, the required number of staff as well as an expedient and effective organisation.

A large number of experienced staff of the nuclear licensing and supervisory authorities has already reached retirement age and left in the last few years or will do so in the years to come. This generation change represents a great challenge for the nuclear licensing and supervisory authorities. Available positions can often only be filled by applicants without relevant nuclear knowledge. This circumstance is countered by internal and external training and further qualification measures as well as suitable measures to maintain competence. The current measures are explained in more detail below for the authorities of the Federation and the *Länder*.

Competence and personnel development at the nuclear regulatory authority of the Federation

So far it has largely been possible to compensate any loss of experience by the documentation of knowledge, by interviewing those who were about to retire and by the commitment of the junior staff.

An employment condition for technical staff is a university degree in the relevant discipline. The knowledge needed for the special tasks (expert nuclear knowledge, administrational knowledge, etc.) is imparted, where required, in special courses during an introductory phase as well as by on-the-job training at the authorities.

The technical training and further qualification of the staff takes place, among other things, through participation in seminars for staff of the authorities organised by the expert organisation Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH on behalf of the BMU for the training and further qualification in particular for younger staff at regular intervals and on various safety-related topics, through simulator and glass model training courses at the Gesellschaft für Simulatorschulung (GfS) as well as through participation in external national and international specialist events. Issues of further qualification are addressed, among other things, in the cooperation talks regularly held between all staff members, also long-standing and experienced staff, and executives.

Competence and personnel development at the nuclear licensing and supervisory authorities of the *Länder*

Maintaining competence also plays an important role for the nuclear licensing and supervisory authorities of the *Länder*. This applies in particular against the background of the situation that the licensing procedures for the decommissioning of the nuclear installations still in operation run parallel to power operation. This temporarily results in a strongly increased workload while it is foreseeable that the staffing needs will decrease after the end of power operation.

Newly recruited staff members take part in the knowledge transfer of the nuclear licensing and supervisory authorities, which is systematically promoted by means of internal training courses and workshops in addition to the regular exchange of information at working level. They are incorporated on the basis of individual plans. The respective initial training plan brings together various measures for training and further qualification measures, introduction to special activities and guidance for independent action. Depending on the intended field of work and already available knowledge, junior staff are trained in all relevant technical and legal areas.

In Baden-Württemberg, for example, the Nuclear Energy Supervision and Radiation Protection Division implemented regulations for staffing and further qualification measures for the personnel in the management system of the division. Regarding the recruitment and further qualification of staff, a catalogue of competences was introduced, comprising eight competence areas. This catalogue is used to ensure the division's requisite competence and qualification in the context of recruiting and further qualification.

In addition, also the long-standing and experienced staff of the nuclear licensing and supervisory authorities keep their technical qualification continuously up to date and participate in the relevant training activities.

Training on power plant simulators and on the glass model of the GfS to illustrate thermohydraulic effects in a pressurised water reactor (PWR) is an important element of training and further qualification for all staff members.

The glass model is a model of a 2-loop PWR made of glass by Kraftwerk Union AG (KWU). The model on a scale of 1:10 was constructed according to the rules of similarity theory and allows the visualisation and observation of thermohydraulic phenomena.

The training programme includes the aforementioned seminars for staff of the authorities as well as the seminars and workshops of the Association of Technical Inspection Agencies (VdTÜV). Another important element of training and further qualification is the participation in national and international specialist conferences.

The prerequisite for employment of technical specialists is a degree from a university of applied sciences or a university degree. Relevant professional experience in trade supervision, at authorized expert organisations, in industry and in science is of advantage. The knowledge needed for the special tasks of the nuclear licensing and supervisory authority is imparted during an introductory phase as well as by on-the-job training at the nuclear licensing and supervisory authority. Work performance and work results are continuously controlled by the superior. Questions of further qualification are the subject of regular appraisal interviews.

The consultation of authorised experts for the various licensing and supervisory procedures, requires the regulatory officials to have, above all, broad, generalist knowledge. For example, they have to verify whether the authorised experts' statements cover all relevant areas and have to come to an administrative decision on the basis of different statements. Some nuclear licensing and supervisory authorities of the *Länder* have appointed so-called technical coordinators which have special knowledge in individual fields and support their colleagues across all installations.

Information and knowledge management system

The institution-wide web-based portal for nuclear safety (Portal für Nukleare Sicherheit (PNS)) was introduced as an instrument for the preservation of knowledge. The portal contains, on the one hand, knowledge pages on selected topics and, on the other hand, collaboration pages where, for example, meeting documents of Federation-*Länder* committees are made available, and it includes areas where documents and results of research and development projects financed by the BMU and other federal departments are documented (project pages). For the knowledge pages, compilations of documents and technical information relevant for nuclear authorities and expert organisations are prepared and provided in an electronically structured form.

The international exchange of information and knowledge for the effective and transparent execution of the AtG and regulatory cooperation is becoming increasingly important. Therefore, the BMU also uses international information networks (such as the International Regulatory Network (RegNet) or the Global Nuclear Safety and Security Network (GNSSN)) and is actively involved in their design.

Financial resources

The financial means available to the nuclear licensing and supervisory authorities for their own personnel and for the consultation of authorised experts are fixed by the *Bundestag* and the *Land* parliaments in their respective budgets. The applicants and licence holders are invoiced by the *Länder* for the project-specific costs of nuclear licensing and supervision. There is no refinancing of the activities of the nuclear licensing and supervisory authority of the Federation (BMU), since the licence holders of the nuclear installations cannot be charged with fees for the supervision of the nuclear federal authority through the *Land* authorities.

Licences for nuclear installations and the supervisory activities of the *Länder* are generally subject to charging. The amount of fees is fixed by law in the Cost Ordinance under the Atomic Energy Act and the Radiation Protection Act (AtSKostV). The costs are paid by the licence holder to the treasury of the respective *Land*. A modification requiring a licence costs between 500 euros and 1 million euros. The costs of supervision are invoiced according to the actual effort for the individual activities or as an annual lump sum for supervision and amount to between 25 euros and 500,000 euros. The remuneration for the authorised experts consulted is also reimbursed by the applicant or licence holder as expenses.

The BMU has an annual budget of approximately 32 million euros at its disposal for research, investigations and the like in the fields of nuclear safety, radiation protection and nuclear supply and waste management. The field of nuclear safety includes the evaluation and assessment of operating experience, studies on special safety-related issues and further development of technical requirements for nuclear facilities as well as work on technical and other specific questions in connection with the licensing and supervision of nuclear installations. Further funds from the budget are used, among other things, for financing the work of the advisory commissions and for involving external experts in international cooperation.

Management systems

Management system at the nuclear regulatory authority of the Federation

The management system of Directorate-General S is based on organisational decrees, schedules of responsibilities, rules of internal procedure and procedural instructions as they generally apply for supreme federal authorities.

For Directorate-General S, this general basis is supplemented in a dynamic process by instruments of planning and strategy development as well as by a description of the main processes that are available to all members of Directorate-General S in an electronic manual, and improvement potentials are determined.

The aim of the management system in the chosen form is to identify future requirements at an early stage, thus enabling targeted and timely action. It is intended to support management staff in carrying out their management tasks and contribute to further increasing the quality and efficiency of work. Furthermore, the documentation of the processes and work instructions ensures that relevant experience is passed on in a targeted manner and is not lost due to the retirement of staff.

Management systems at the nuclear licensing and supervisory authorities of the *Länder*

The work routines and processes of the nuclear licensing and supervisory authorities of the *Länder* are largely defined and regulated uniformly by the established organisational procedures for *Land* ministries. The concrete processes in matters of supervision and approval are regulated by a directorate-internal management system. These management systems are continuously adapted and further developed by the various authorities, taking into account changing requirements. Examples of adaptations in recent years are, for example, the adaptation of supervisory planning to the post-operational phase or decommissioning. The documentation of processes in the supervisory procedure also ensures that experience is passed on and is not lost due to the retirement of staff.

Support by the federal offices, advisory commissions and authorised experts

Federal Office for Radiation Protection (BfS)

The BfS is a subordinate authority of the BMU in the field of radiation protection and nuclear safety and supports the BMU within the meaning of the Convention on Nuclear Safety through its divisions “Medical and Occupational Radiation Protection”, “Emergency Preparedness & Response” and “Environmental Radioactivity". This includes in particular the following tasks:

- keeping of a register of occupational radiation exposure,
- the control programme for emission monitoring of nuclear installations,
- large-scale monitoring of environmental radioactivity,
- in the event of an accident with radiological consequences, the preparation of the radiological situation report (RLB) including the coordination of all radiological measurements in the environment.

The type and scope of support is agreed annually between the BMU and the BfS within the framework of the annual planning.

Federal Office for the Safety of Nuclear Waste Management (BfE)

As a subordinate authority of the BMU, the BfE performs the following statutory tasks:

- licensing for storage and transport of heat-generating radioactive waste,
- the search for and selection of a site for a disposal facility for high-level radioactive waste (site selection procedure),
- task-related research,
- planning approval and licensing of disposal facilities, including approvals under mining law and permits under water law, and
- supervision of disposal under nuclear and radiation protection law.

Directorate-General “Nuclear Safety and Supervision in Nuclear Waste Management” supports the BMU in the following priority areas related to the Convention on Nuclear Safety:

- documentation of the licensing status and the remaining electricity production rights of nuclear installations,
- documentation and examination of the reporting obligation of reportable events (Incident Registration Centre),
- selected safety issues,
- international cooperation,
- national and international regulations, and
- supervision and administration of research projects in the field of reactor safety research.

The type and scope of support is agreed annually between the BMU and the BfE within the framework of the annual planning.

Reactor Safety Commission (RSK), Commission on Radiological Protection (SSK) and Nuclear Waste Management Commission (ESK)

The BMU is regularly advised by the commissions RSK, SSK and ESK. The RSK provides advice in matters of nuclear safety including matters with respect to the physical protection of nuclear installations. The SSK provides advice in matters of protection against ionising and non-ionising radiation, and the ESK in matters of nuclear waste management. Independence, qualification and reflection of the technical-scientific range of opinions is to be ensured in the commissions. The members are obliged by statutes to express their opinion in a neutral and scientifically sound manner and are appointed by the BMU. The results of the commission's consultations are formulated in the form of general recommendations and statements on individual cases and published. For further information on the consultations of the RSK and on how the authorities deal with the results of the consultations, see process 11 in the Handbook on Cooperation between the Federation and the *Länder* in Nuclear Law (www.rskonline.de, www.ssk.de, www.entsorgungskommission.de).

Authorised experts of the Federation and the *Länder*

According to § 20 AtG, the authorities in charge may consult authorised experts in the licensing and supervisory procedures. These can be both independent experts and independent technical expert organisations (authorised experts). The authorised experts are contractually obliged to be impartial and independent from the economic interests of the nuclear licence holders to be assessed as well as to provide technical qualification and continuous maintenance of qualification for the personnel employed. Authorised experts are clearly mandated by the supervisory authorities and commissioned for specific activities. The authorised experts prepare test reports, statements and expert opinions. The authority's decision-making authority is not transferred to them. The nuclear licensing and supervisory authority is not bound by the results of the examinations of the authorised experts.

The BMU draws on the external expertise of several technical expert organisations. In particular, these are the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Brenk Systemplanung GmbH, Physikerbüro Bremen and Öko-Institut e.V.

As the competent licensing and supervisory authority, the BfE commissions expert organisations such as the TÜV, e.g. within the framework of licensing procedures for the storage of spent fuel in storage and transport casks, and the Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und -prüfung (BAM)). In addition, the BfE is involved in the research coordinated by the BMU.

The nuclear supervisory authorities of the *Länder* usually seek advice from the major technical expert organisations of the TÜVs (Technical Inspection Association, German: Technischer Überwachungsverein = TÜV, i.e. TÜV Nord, TÜV Süd and TÜV Rheinland). As a rule, framework agreements exist between the nuclear licensing and supervisory authorities of the *Länder* and the TÜVs, which oblige TÜVs to perform certain tasks in the long term and to provide the necessary know-how including appropriately qualified personnel. This ensures that the relevant TÜV, as the technical expert organisation of the respective nuclear licensing and supervisory authority of the *Land*, is almost permanently present in the nuclear installation by carrying out individual inspections and test activities. In particular, the technical expert organisation can thus build up qualified knowledge of the entire plant from the various activities over a longer period of time. Authorised experts cannot take any sovereign measures, but they are contractually obliged to report immediately any facts or findings to the supervisory authority that require official action.

With the involvement of authorised expert, an examination on the safety-related issues is made which is independent of that of the applicant. For this purpose, the authorised experts conduct their own checks and calculations, preferably with methods and computer codes different from those used by the applicant. The persons involved in preparing the expert opinions are not bound by any technical instructions. They are reported to the respective nuclear licensing and supervisory authority by name or are known to it.

The scope of expert services is always determined by the competent nuclear licensing and supervisory authority.

Integrated Regulatory Review Service (IRRS) Mission 2019

Article 8e(1) of Directive 2009/71/Euratom requires EU Member States to carry out a self-assessment every ten years of the national legislative, regulatory and organisational framework for the nuclear safety of nuclear installations, including the competent regulatory authorities, and to invite them to a subsequent peer review. Germany has laid down this obligation in the AtG (§ 24b(1)). The European Nuclear Safety Regulator Group (ENSREG) and the International Atomic Energy Agency (IAEA) have agreed in a Memorandum of Understanding to use the Integrated Regulatory Review Service (IRRS) of the IAEA for this purpose.

At the invitation of the BMU, the second IRRS mission to Germany took place from 31 March to 12 April 2019. The scope of the IRRS mission was the regulatory framework for the safety of nuclear installations, as well as installations for supply and disposal, occupational radiation protection and emergency preparedness and response. In addition to the nuclear regulatory authorities of the BMU and BfE, the nuclear licensing and supervisory authorities of the *Länder*

- Baden-Württemberg,
- Bavaria,
- Hesse,
- Mecklenburg-Western Pomerania,
- Lower Saxony,
- North Rhine-Westphalia, and
- Schleswig-Holstein

have participated in the IRRS mission. A comprehensive self-assessment was carried out prior to the mission. Identified improvement measures were recorded in a national action plan. The self-assessment process carried out in advance as well as the results of the mission itself were assessed very positively by the IRRS review team.

As an overall result, it is confirmed to Germany that its regulatory framework for nuclear safety meets the internationally applicable standards. The review team found that Germany’s nuclear licensing and supervisory authorities are mature and competent and highlighted the effective cooperation with other organisations and interested parties.

The Review Team identified a “good practice” for its Integrated Measuring and Information System for the Monitoring of Environmental Radioactivity (IMIS) (→ Article 15). With the IMIS system, Germany has reached a very high level in the field of emergency preparedness and response, which even exceeds the internationally required standards of the IAEA. Also regarded as positive (“area of good performance”) were i.a.

- the comprehensive legal requirements for scenario-based emergency plans of the Federation and the *Länder*,
- the joint portal for knowledge management of the nuclear licensing and supervisory authorities of the Federation and the *Länder*, and
- the effective coordination between supervisory and prosecution authorities.

The review team also made some recommendations and suggestions to improve the framework for nuclear safety. Most of these had already been identified in the previous self-assessment by the German licensing and supervisory authorities and were anchored in a national action plan. The National Action Plan will be revised on the basis of these results.

The Advance Reference Material (ARM)[8] and the report on the IRRS Mission 2019 are published on the BMU website (https://www.bmu.de/en/topics/nuclear-safety-radiological-protection/nuclear-safety/international/irrs-mission/).

8 (2) Separation of functions in the supervision and utilisation of nuclear energy

Separation of functions in the supervision and utilisation of nuclear energy

Article 8 (2) of the Convention on Nuclear Safety contains a protective provision which stipulates the organisational-structural separation of the licensing and supervisory functions of the state from its promotion function. The principle of separation has also been enshrined in Article 5(2) of Council Directive 2009/71/Euratom and amending Directive 2009/71/Euratom of 25 July 2014 establishing a Community framework for the nuclear safety of nuclear installations.

Realisation in Germany

The nuclear licensing and supervisory authorities of the Federation and the *Länder* are administrative state authorities. The Basic Law of the Federal Republic of Germany (GG) requires them to act according to law and justice (Article 20(3) GG). In this respect, emphasis is laid on the obligation pursuant to the AtG to take the necessary precautions against damage resulting from the construction and operation of the installation as are necessary in accordance with the state of the art in science and technology.

Organisationally, a distinction has to be made between the activities of the competent nuclear licensing and supervisory authorities on *Länder* level and the powers of supervision and instruction held by the Federation.

On the level of the *Länder*, the principle of separation of Article 8 (2) of the Convention on Nuclear Safety is adhered to on the basis of the organisational provisions realised in the *Länder*. The effective separation of the bodies responsible for nuclear licensing and supervision from those responsible for the use of nuclear energy within the framework of general energy policy or the promotion of the energy industry is ensured by the fact that different ministries (the Federal Ministry for Economic Affairs and Energy (BMWi) as the lead ministry in the energy sector including energy research and the Federal Ministry of Education and Research (BMBF) for basic research) are in charge of and responsible for functions at the federal level, and different and independent organisational units are in charge of and responsible for tasks within a ministry at the *Land* level.

To support the administrative state authorities in technical matters, these can consult authorised experts, acting under civil law, who in turn are obliged to deliver impartial and qualified statements on the results of their reviews (→ Article 7 (2ii), 7 (2iii) and Article 8 (1)).

The right of the Federation derived from Articles 85(3) and 87c GG to give instructions to the *Länder* executing the AtG concerning issues related to the licensing and supervision of nuclear installations lies within the competence of the BMU. The BMU does not fulfil any functions relating to the use and promotion of nuclear energy.

The BMU pursues the development of new safety solutions to derive important knowledge concerning the safety of German nuclear installations in operation.

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[8] Advanced Reference Material, IRRS Mission 2019, Germany, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, https://www.nuklearesicherheit.de/fileadmin/user_upload/PDF/irrs_arm_germany_en.pdf

In contrast to the above-mentioned government authorities of the Federation and the *Länder*, the licence holders of nuclear installations, in their function as users and maybe promoters of nuclear power, represent commercial enterprises under civil law. They are either power utilities themselves or are composed of shareholders from the ranks of the German power utilities.

These shareholders are also commercial enterprises under civil law, usually joint-stock companies (→ Article 11 (1)) and have no influence on the safety-directed action of the nuclear licensing and supervisory authorities.

Reporting of the regulatory body

Once a year, the BMU shall report to the German *Bundestag* and the *Bundesrat* on the development of environmental radioactivity in the environment, as stipulated in § 164(2) StrlSchG.

The BMU informs the Committee on the Environment, Nature Conservation and Nuclear Safety of the German *Bundestag* quarterly in the form of an overview list on reportable events in installations for the fission of nuclear fuel in the Federal Republic of Germany, i.e. nuclear power plants and research reactors with a continuous thermal power above 50 kW. In addition to the list, the BMU informs about the publication of detailed monthly and annual reports on reportable events in German nuclear installations and research reactors through the BfE on the BfE web pages.

The overall responsibility for informing the general public in a transparent manner lies with the competent authorities of the relevant *Länder*. In addition to public participation in nuclear licensing procedure as required by law, comprehensive information is provided via the Internet and press releases. Inquiries on nuclear issues are generally answered in writing. Moreover, some *Länder* with nuclear installations established special independent commissions at the respective sites at the request of the citizens. These commissions are to actively inform the local public in regular sessions on safety issues or details of nuclear installations.

On 16 February 2018, the portal on nuclear safety was launched in German and English (www.nuklearesicherheit.de and www.nuclearsafety.de). The portal was developed by the BMU together with the *Länder*, the BfS and the BfE. The aim is to provide the population with simplified access to information on the activities of the nuclear licensing and supervisory authorities of the Federation and the *Länder* in the field of nuclear safety via a central website on the Internet. In addition to information on the nuclear installations in Germany and on emergency preparedness and response, an overview of the regulatory system in Germany and of European and international activities of the German nuclear licensing and supervisory authorities are provided as well as basic knowledge on nuclear technology.

9 Responsibility of the licence holder

ARTICLE 9 RESPONSIBILITY OF THE LICENCE HOLDER

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

Legal and regulatory requirements

Article 6(1) of Directive 2009/71/Euratom and amending Directive 2014/87/Euratom of 25 July 2014 require Member States to ensure that "the prime responsibility for the nuclear safety of a nuclear installation rests with the licence holder". This is fulfilled by the regulations of the Atomic Energy Act (AtG) on licensing and supervision, which are based on the principle of the licence holder's responsibility. This requirement is implemented in Germany in § 7c(1) AtG. It states: "The responsibility for nuclear safety shall fall to the holder of the licence of the nuclear installation. This responsibility cannot be delegated and also extends to the activities of the contractors and subcontractors whose activities may impair the nuclear safety of a nuclear installation."

According to § 7(2) AtG, a licence for construction and operation may only be granted if the applicant proves that the necessary technical and organisational precautions for safe operation have been taken.

Furthermore, § 7(2) AtG stipulates that the licence for construction and operation of a nuclear installation may only be granted if there are no doubts as to the trustworthiness of the applicant and the persons responsible. In addition, these persons must have the necessary technical qualification.

The licence holder of a nuclear installation is a radiation protection executive (§ 69 StrlSchG). In corporate enterprises, the tasks of the radiation protection executive are performed by a person authorised to represent the licence holder. The position and duties of the radiation protection executive are regulated in §§ 70 to 72 StrlSchG. The radiation protection executive is obliged to take protective measures to protect man and the environment from the harmful effects of ionising radiation, taking due account of the state of the art in science and technology. For this purpose, suitable rooms, equipment and devices have to be provided. Furthermore, the radiation protection executive shall ensure properly organised operations and sufficient numbers of qualified personnel.

The radiation protection executive shall appoint the required number of radiation protection supervisors for the management or supervision of activities to ensure radiation protection during the operation of the nuclear installation. The radiation protection executive shall also remain responsible even in the case of such appointment.

Furthermore, the Nuclear Safety Officer and Reporting Ordinance (AtSMV) requires the appointment of a nuclear safety officer. The rights and duties of the nuclear safety officer are regulated in §§ 3 to 5 AtSMV. His tasks include the evaluation and implementation of operating experience as well as the verification of the correctness and completeness of the reporting of reportable events (→ Article 19 (vi) and 19 (vii)).

With the introduction of § 7c AtG in 2010, the licence holder also became legally required to introduce a management system giving due priority to safety (→ Article 10).

Further requirements for the responsible personnel are laid down in the Guideline Concerning the Proof of the Technical Qualification of Nuclear Power Plant Personnel. Accordingly, the manager of the installation is ultimately responsible for the safe operation of the entire installation and, especially, for the fulfilment of the provisions and requirements under the nuclear law and nuclear licence permits as well as for the cooperation of all departments. He is authorised to give orders to the heads of departments or sections.

The heads of departments or sections are authorised to give orders to their subordinate personnel.

The person responsible for stand-by service assumes the function of the manager of the installation if the latter and his deputy are not present.

The task of the responsible shift personnel (shift supervisors, their deputies and reactor operators) is to operate the nuclear installation in accordance with the written operating instructions and with the prescribed operating schedule during normal operation of the installation and to take appropriate action in the event of an accident.

When using external personnel, the licence holder has to make sure that the necessary knowledge according to the guideline relating to the assurance of the necessary knowledge of the persons otherwise engaged in the operation of nuclear power plants is ensured, if necessary by persons supporting the external personnel. This also applies to the case that knowledge is communicated by the contractor. This is to be demonstrated to the nuclear licensing and supervisory authority upon request.

In implementation of Directive 2014/87/Euratom, the licence holder is obliged pursuant to § 7c(3) AtG to provide for adequate procedures and precautions for on-site emergency preparedness. The licence holder shall provide for preventive and mitigative measures of on-site emergency preparedness,

- which neither impair the specified normal operation nor the use of safety and emergency equipment as specified by their design and ensure the compatibility with the safety concept,
- which remain effective in case of accidents that affect or impair several units at the same time,
- the operability of which is ensured by maintenance and in-service inspections,
- which are regularly used and inspected in training exercises, and
- which are regularly reviewed and updated, taking into account the knowledge gained from the training exercises and accidents.

The licence holder shall provide for and maintain permanent adequate financial and human resources required for it (§ 7c(2)2 AtG).

In addition, the licence holder is legally obliged (§ 7c(2)4 AtG), within the framework of his communication policy and in compliance with his rights and obligations, to inform the public

- on the specified normal operation of the nuclear installation, and
- on reportable events and accidents,

paying special attention to the local population and stakeholders in the vicinity of the nuclear installation.

Implementation and measures by the licence holders

The elements of an Integrated Management System (IMS) are defined in safety standard KTA 1402 “Integrated Management System for the Safe Operation of Nuclear Power Plants” and are specified by detailed requirements. A key element is the responsibility of the management. Related requirements are as follows:

- **Responsibility of the company management**
  The company management has the responsibility to ensure the safe operation of their installations. To this end, it has to implement various issues. These include the development, introduction and continuous improvement of an IMS, the definition, implementation and communication of the company policy and objectives for a high level of safety and a strong safety culture, the establishment of principles for the organisational and operational structure and

the regular review of the effectiveness of the management system as well as the appointment of the manager of the installation.

- **Responsibility of the management of the installation subordinate to the company management**
  This includes ensuring the safe operation of the installation, the development, introduction and continuous improvement of an integrated management system, compliance with legal, regulatory and safety requirements, drawing-up and implementation of the installation's policy in line with the company policy, the implementation of the organisational and operational structure at the installation in accordance with the principles laid down by the company management, guaranteeing the necessary competences and qualification of the personnel, and the regular review of the effectiveness of the management system.

Further requirements are related to the IMS officer, the process supervisors and the management review.

All licence holders have committed themselves in fundamental documents, such as management principles or corporate policies, to giving priority to the safety of the nuclear installations over all other business objectives. Requirements for the management systems are formulated in the "Safety Requirements for Nuclear Power Plants" and put in concrete terms in safety standard KTA 1402. Examples of safety-related business objectives are the following:

- The safety of nuclear installations has the highest priority. It is based on mature technology, adequate organisational (administrative) specifications and qualified personnel.
- Safety-relevant processes are critically questioned, monitored and further developed.
- All actions/activities/measures are characterised by the necessary safety awareness (high significance of safety culture).
- The technical safety level reached and the condition of the nuclear installations in compliance with licensing requirements are maintained and further developed by means of adequate monitoring and maintenance concepts as well as by modifications of the installation.
- The timely and comprehensive exchange of experience on safety-relevant events or findings is of great importance for the German nuclear installations.

Safety standard KTA 1402 further states that the IMS is primarily an instrument for the licence holder to assume his responsibility for the safety of the installation at all levels of management.

The licence holder has to demonstrate to the competent nuclear licensing and supervisory authority that the requirements resulting from the Guideline Concerning the Proof of the Technical Qualification of Nuclear Power Plant Personnel[9] are fulfilled.

The licence holders of the German nuclear installations are members of VGB PowerTech e.V. (VGB), the international technical association for generation and storage of power and heat. VGB is an association of companies for which the operation of power plants and the associated technology represents an important basis for their entrepreneurial action. Under the umbrella of the VGB, joint research and development in the area of "nuclear power plants" is conducted and promoted. VGB usually also organises the development of concepts, activities, and the development of the state of the art in science and technology as well as the exchange of experience across the nuclear installations.

Since the end of the 1980s, the licence holders have implemented an on-site emergency preparedness system with preventive and mitigative emergency measures which has been successively supplemented in the following years according to the progress of knowledge from safety research and results from reviews for applicability of nuclear events to other installations. The implementation was

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9 https://www.bfe.bund.de/SharedDocs/Downloads/BfE/EN/hns/a1-english/A1-05-12.html

carried out in nuclear procedures and fulfils all requirements for the scope of on-site emergency preparedness, which since 2017 has also been specified in the legal provisions pursuant to § 7c(3) AtG. Details on implemented measures are comprehensively presented and explained in particular in Article 6 (→ Tables 6-2 and 6-3, 14 (i), 16 (1) and 18 (iii).

In exercising their responsibility and fulfilling their obligation to inform the public (§ 7c(4) AtG), the licence holders of nuclear installations have set themselves the goal of informing the public by means of transparent and open communication. This includes e.g.

- media work,
- external communication of reportable events,
- crisis communication,
- external communication of power-plant-specific issues (operation, overall maintenance and refuelling outages, maintenance and modernisation projects), within the bounds of possibility, and
- public relations work at the site, e.g. on-site discussion rounds.

Regulatory review

For the German nuclear power plants, the organisation charts, the persons responsible and their area of responsibility are documented in the plant personnel organisation (PBO). The PBO is part of the safety specification (→ Article 19 (ii)) and a licensing document. During the licensing procedure for the nuclear installation, the nuclear licensing and supervisory authority checks whether the responsibilities are specified in an appropriate manner. The licence holder informs the licensing and supervisory authority of any changes in the organisation chart or of persons responsible. Any changes in the PBO are either subject to licensing by the nuclear licensing authority or to the approval of the nuclear supervisory authority. Documents such as the operating manual (BHB) or the emergency manual (NHB) are examined either by the authorised expert or assessed by the nuclear licensing and supervisory authority itself.

In addition to the required technical qualification (→ Article 11 (2)), the nuclear supervisory and licensing authorities also check the trustworthiness of the responsible persons of the licence holder and all persons working in safety-relevant areas. For the assessment of trustworthiness, the findings of the police authorities are queried, among other things. The persons may only start to work if the supervisory authority has no doubts as to their trustworthiness and agrees to their appointment.

Moreover, the nuclear licensing and supervisory authority also checks the trustworthiness of the applicant or licence holder (of a corporation) or the persons representing him (e.g. the board members or directors).

The nuclear licensing and supervisory authority holds meetings with the board members or directors of the licence holder to check how the persons responsible on the part of the licence holders fulfil their obligations regarding the responsibility for nuclear safety. Here, general questions relating to safety and to the relationship between nuclear licensing and supervisory authority and licence holder may be brought up for discussion, with the nuclear licensing and supervisory authority paying heed to ensuring that the licence holder's prime responsibility for safe operation is not impaired.

Altogether, all supervisory activities of the nuclear licensing and supervisory authorities are independent reviews of the extent to which the licence holder fulfils his responsibility for the nuclear safety of the installation. The regulatory activities in this context comprise:

A Control of the condition of the installation and its function

a. Participation in in-service inspections
b. Inspection of modifications and repairs as well as of subsequent cores

c. Accompanying controls of modifications and repairs as well as of subsequent cores

B Control of the installation's operating behaviour

a. Evaluation of operating results and measured values

b. Evaluation of accidents and special occurrences

c. Monitoring of the surroundings of the installation

C Control of the licence holder’s behaviour

a. Review of the organisation of the installation

b. Review of the technical qualification and trustworthiness

c. Review of operational management

d. Review of the licence holder's emergency preparedness planning

D Other activities

a. Control of compliance with requirements

From such an integrated regulatory assessment, requirements are also derived for human and technical resources needed to be able to support and accompany effective on-site management in the best possible way in order to control accidents or take measures to mitigate the consequences.

10 Priority to safety

ARTICLE 10 PRIORITY TO SAFETY

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

Legal and regulatory requirements

The priority of safety is specified in § 1 no. 2 of the Atomic Energy Act (AtG). There, the protection of life, health and real assets against the hazards of nuclear energy and the harmful effects of ionising radiation. Furthermore, § 7c(1) AtG stipulates that the responsibility for nuclear safety shall fall to the holder of the licence of the nuclear installation and that this responsibility cannot be delegated. Accordingly, § 7c(2)1 AtG requires that the licence holder shall install and apply a management system giving due priority to nuclear safety. In the substatutory regulations, the "Safety Requirements for Nuclear Power Plants" contain fundamental organisational requirements for the management of the company operating, amongst others, the nuclear installation for electricity production as well as for the management of the installation itself. This also includes the integrated management system (IMS), in which all safety-related objectives and requirements have to be considered, and it contains the task of the licence holder to maintain a highly developed safety culture and to continually improve it.

In the "Safety Requirements for Nuclear Power Plants", priority to safety is further specified as follows:

- The licence holder shall give priority to safety over all other business objectives.
- The prime objectives of the IMS are specified as:
  - the guarantee of safety,
  - the continual improvement of safety, and
  - the promotion of safety culture.
- In addition, the term of safety culture, being essential in the context of giving priority to safety, is clearly defined: "Safety culture is determined by a safety-oriented attitude, responsibility and conduct of all staff required for ensuring the safety of the plant. For this purpose, safety culture comprises the assembly of characteristics and attitudes in a company and of individuals which establishes that, as an overriding priority, nuclear safety receives the attention required by their significance. Safety culture concerns both the organisation and the individual."

The IMS is seen as a fundamental tool to ensure, continually improve and prioritise safety. Within the national nuclear regulations, the requirements for the IMS are further specified in nuclear safety standard KTA 1402. Both the "Safety Requirements for Nuclear Power Plants" and KTA 1402 require applying the integrative approach for the management system to prevent conflicts of objectives between other business objectives and safety and thus to give due priority to nuclear safety. Here, priority to safety is implicitly required as part of the company policy. The implementation of the process-oriented and integrated management system described in the KTA safety standard ensures the necessary procedures to achieve this business objective. It also serves to strengthen safety culture and the continuous self-monitoring and evaluation of all processes. This is implemented through the so-called Plan-Do-Check-Act cycle. Furthermore, safety standard KTA 1402 specifies requirements for safe operation, organisation at different levels, monitoring, analysis, assessment and improvement as well as for the tracking of improvement measures as part of the IMS.

Implementation and measures by the licence holder

All German licence holders have committed themselves in management principles or corporate policies to giving priority to the safety of the nuclear installations over all other business objectives (→ Article 9). To implement these principles, both the respective management system has been introduced and measures for the safety-oriented behaviour of the personnel have continuously been further developed.

Before publication of nuclear safety standard KTA 1402 in 2012, already in 2008, the German licence holders of nuclear installations presented the VGB guideline “VGB-Leitfaden zum Sicherheitsmanagement”. This guideline had been based on the concept for the optimisation of the safety management system (“Konzept zur Optimierung des Sicherheitsmanagementsystems” (SMS)) (1999/2002) and describes

- the improvement of the safety level in the German nuclear installations,
- the principles and objectives of an SMS, and
- the requirements for an SMS to ensure a high level of safety.

The VGB guideline was introduced in the process of drawing up nuclear safety standard KTA 1402 by representatives of the licence holders. The safety culture assessment system of the VGB (VGB-SBS) is an instrument for self-assessment applied by the licence holder and an element to strengthen and monitor safety culture. It also serves, according to the users, to review the effectiveness of the management system. The nuclear licensing and supervisory authorities are informed about the performance and main results of the VGB-SBS.

Regulatory review

Within the framework of licensing of a nuclear installation and within the framework of supervision of its operation, the nuclear licensing and supervisory authority regularly checks the licence holder for compliance with the legal requirements which must ensure giving priority to the safety of the installation. This includes provisions by the licence holders in order to fulfil their responsibility for the safe operation of the nuclear installations and to give priority to safety.

Through discussions with the management staff of the licence holder, the nuclear licensing and supervisory authority verifies whether priority is given to the safe operation of the nuclear installations also at the strategic level. In this respect, the statements and the behaviour of the licence holder’s management staff are of particular importance. The competent nuclear licensing and supervisory authorities of the *Länder* obtain information about the safety-oriented behaviour of the licence holder’s operating staff e.g. by extensive controls during on-site inspections and from the evaluation of reportable events and other occurrences (→ Article 19).

The competent nuclear licensing and supervisory authority of the *Land* ensures that the licence holders apply the IMS and check, in particular, whether and how priority to safety is anchored in the basic principles of the management system. Some nuclear licensing and supervisory authorities of the *Länder* also review the effectiveness of the management system. In addition to the basic principles, the focus is on those processes where the priority of safety is particularly clear. These are e.g. business objectives or the management review.

It is checked, e.g., whether

- a selected process and the interfaces considered are described and whether this description is based on a systematic approach,
- the internal and external requirements which are to be placed on processes are met,

- processes and activities, as described in the process documentation, are performed and maintained in compliance with the regulations, and
- whether an effective review of the process under consideration is performed by the licence holder.

In addition, some of the nuclear licensing and supervisory authorities of the *Länder* use indicators to verify the safe operation of the installations (safety performance) by the licence holder and to align their activities accordingly. These safety performance indicators are partly established by the licence holder or by authorised experts and reported to the competent nuclear licensing and supervisory authorities of the *Länder*. The other part of the indicators is established by these themselves. Examples of the areas in which the indicators are surveyed are event reports, false alarms, simulations, qualifications, results of inspections and in-service inspections, activity releases and non-nuclear accidents/incidents.

Depending on the *Land*, other assessment criteria may also be considered in the assessment of the licence holder's safety management. So, for example, the nuclear supervisory authority of the *Land* of Baden-Württemberg currently uses 33 safety performance indicators and the assessment system "KOMFORT" (catalogue for recording organisational and human factors during on-site inspections). These are regularly further reviewed with regard to their validity and use for nuclear supervision, quality of data collection as well as frequency of data collection and evaluation. The evaluations of these and other indicators are discussed with the licence holder together with other findings from nuclear supervision. The results are used for assessing the safety management of the licence holder of the nuclear installation. With the help of KOMFORT, observations made and impressions gained besides the actual inspections and which are related to safety culture are systematically collected and evaluated. In their entirety, these provide an opportunity to identify certain trends in the nuclear installation which could adversely affect safety, and which would not have arisen from individual considerations, observations and impressions.

In general, the use of such indicators serves as an early warning system for the change of factors that could, directly or indirectly, have adverse effects on the safety of the installation. The causes of such changes can usually not be derived from the indicators themselves. To this end, it is required to investigate the cause of the changes in meetings with the licence holders or by detailed analyses.

Internal measures of the authorities for giving priority to safety

Giving priority to safety is one of the basic principles for the work of the nuclear licensing and supervisory authorities of the Federation and the *Länder*. This principle is implemented in the task descriptions of the nuclear licensing and supervisory authorities, and it is concretised in supervisory practice. The nuclear licensing and supervisory authorities and their staff are bound by the legal provisions on licensing and operation of nuclear installations. Accordingly, the protection of man and the environment and thus the safety of a nuclear installation must have top priority in all operations and measures. This also applies to the processes within the nuclear licensing and supervisory authorities of the Federation and the *Länder*.

Moreover, the nuclear licensing and supervisory authorities of the Federation and the *Länder* base their actions on self-defined guiding principles or mission statements, which further concretise the principle of giving priority to safety. The prime objective of the nuclear licensing and supervisory authorities of the Federation and the *Länder* is the continuous improvement of the safety of nuclear installations and the permanent supervision and monitoring of safety. The use of internal resources and the scope of support by authorised experts are oriented towards the safety significance of the tasks and issues to be clarified.

Progress since 2017

In Germany, additional internal measures of the nuclear licensing and supervisory authorities of the Federation and the *Länder* have been taken since 2017 in order to further concretise the priority of safety.

The priority of safety is decisively determined by the safety culture of the nuclear licensing and supervisory authorities. This includes the entirety of the characteristics and behaviours of the organisation as a whole and results from the safety-oriented attitude, responsibility and behaviour of all its staff and in particular of its management.

In order to further develop the safety culture, the nuclear licensing and supervisory authorities of the Federation and the *Länder* developed a common understanding of their safety culture and put it down in writing it in a policy paper. It covers the fields of nuclear safety, nuclear security and radiation protection in nuclear installations and of nuclear fuel transports.

The policy paper takes into account current international developments in this area. In particular, the principles of the OECD/NEA (Organisation for Economic Co-operation and Development/Nuclear Energy Agency) on safety culture in supervisory authorities published in 2016 were applied. For the nuclear licensing and supervisory authorities of the Federation and the *Länder*, this results in the following principles to maintain and further develop their safety culture:

1. All staff of the licensing and supervisory authorities assume their responsibility for nuclear safety and radiation protection and demonstrate this through their safety-oriented actions.
2. The management staff at all levels of the licensing and supervisory authorities promote the positive development of the safety culture and act as role models.
3. The licensing and supervisory authorities maintain a culture that supports cooperation and open communication.
4. The licensing and supervisory authorities pursue a holistic approach to nuclear safety and radiation protection.
5. The licensing and supervisory authorities promote continuous improvement, learning, self-assessment and self-reflection at all levels.

The policy paper adopted by the *Länder* Committee for Nuclear Energy (LAA) at its meeting on 6/7 June 2019 forms the basis for the further development and concretisation of the safety culture in the individual authorities.

11 Financial and human resources

ARTICLE 11 FINANCIAL AND HUMAN RESOURCES

1. Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.
2. Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.

11 (1) Financial resources – legal and regulatory requirements

According to § 7(2) of the Atomic Energy Act (AtG), a licence may only be granted if, among others, “there are no known facts giving rise to doubts as to the reliability of the applicant and of the persons responsible for the construction and management of the installation and the supervision of its operation” and “the necessary precautions have been taken in the light of the state-of-the-art of science and technology to prevent damage resulting from the construction and operation of the installation.”

The licensing prerequisite of reliability also includes the necessary financial capacity and the economic credibility of the applicant. The provision of the necessary resources is thus a prerequisite for ensuring the necessary precautions against damage in accordance with the state of the art in science and technology. The required reliability and precaution against damages are also criteria for supervision during operation (→ Article 7 (2iii)). According to § 17 AtG, the competent supervisory authority may revoke the licence if the licensing prerequisites are no longer fulfilled at a later point in time and cannot be fulfilled within a reasonable time.

According to § 7c AtG, the responsibility for nuclear safety shall fall to the holder of the licence of the nuclear installation. Furthermore, according to § 7c(2)2 AtG, the holder the licence shall be obliged to provide for and maintain permanent adequate financial and human resources to fulfil his obligation regarding the safety of the particular nuclear installation.

According to § 72 StrlSchG it is one of the duties of the radiation protection executive to ensure that certain regulations are complied with, “in particular by providing suitable rooms, equipment and devices, by properly organizing operations and by providing sufficient and suitable personnel”. Thus, the requirement to provide the necessary financial resources for operation and the post-operational phase is implicitly derived from the duties of the radiation protection executive (→ Article 9).

In order to be able to bear the follow-up costs connected with the operation of the nuclear installations, the licence holders are obliged under commercial law to set aside provisions for decommissioning and dismantling of the installations and for the proper packaging of the radioactive waste during operation. The storage and disposal of radioactive waste is the responsibility of the Federation.

The non-detrimental utilisation of radioactive residues and of disassembled or dismantled radioactive components or their direct disposal as radioactive waste is regulated in § 9a AtG.

Arrangements to ensure that financial resources are available in case of a nuclear event caused by a nuclear installation (liability rules) are regulated in §§ 25 to 40 AtG in addition to the provisions of the “Paris Convention”. § 38 AtG regulates the compensation for damage from the Federation (Federal Republic of Germany) for cases where the provisions of the Paris Convention and other relevant international agreements do not apply.

Implementation by the licence holders

Within the framework of management principles and corporate policies, the licence holders have committed themselves to maintaining a high level of safety, to carrying out adequate backfitting measures and to providing sufficient financial resources.

To cover the follow-up costs of the operation of the nuclear installations, the licence holders continuously set aside provisions for decommissioning and dismantling of the installations and for the proper packaging of the radioactive waste. In July 2017, the provisions formed by the licence holders totalling more than 24 billion euros were transferred to the specially established foundation "Fonds zur Finanzierung der kerntechnischen Entsorgung" (Fund for the Financing of Nuclear Waste Management). All financial obligations in this regard have thus been transferred to the Federal Office for the Safety of Nuclear Waste Management (BfE). This money is intended for the storage of radioactive waste, the exploration and construction of facilities for disposal and for disposal itself.

§ 14 AtG regulates the third party liability insurance and other forms of financial security of the licence holder in connection with the "Paris Convention" and establishes a legal connection to claims in case of damage according to the Insurance Contract Act[10].

Regulatory review

§ 13 AtG stipulates that in the licensing procedure, type, terms and amount of the financial security shall be determined that is to be provided by the applicant to meet the legal liability to pay compensation for damages (financial security). Such determination shall be renewed every two years and in the event of a material change in circumstances and conditions.

The change of the licence holder of an installation subject to licensing, e.g. in case of sale of the nuclear installation to another company, requires licensing pursuant to § 7 AtG. Changes in the legal form of the company subject to licensing also include those that may have an influence on the financial resources of the licence holder.

The operation of a nuclear installation is subject to permanent nuclear supervision. Should it turn out that the financial security does not comply with the determination and proof of financial security complying with the determination is not furnished within a reasonable period of time, the nuclear supervisory or licensing authority may order measures up to the revocation of the licence (§ 17(4) AtG). The same applies pursuant to § 17(5) AtG in the case of substantial hazards to the personnel, third parties or the general public and if subsequently imposed obligations cannot remedy the situation within a reasonable period of time.

11 (2) Human resources and personnel qualification

To ensure safety at the German nuclear installations, § 7c AtG requires the licence holders to provide appropriate human resources. Furthermore, they have to provide for the education and further training of staff with tasks in the field of nuclear safety. The required qualification of the staff is specified in various guidelines. These are listed and explained below:

- Guideline concerning the proof of the technical qualification of nuclear power plant personnel: This guideline lays down the necessary requirements with regard to training and knowledge for the responsible plant personnel, consisting of the plant manager, the heads of department or section, the persons responsible for stand-by service, the training managers, the head of quality assurance and the nuclear safety officer as well as their deputies. The necessary

10 Insurance Contract Act of 23 November 2007 (Federal Law Gazette I p. 2631), as last amended by Article 15 of the Act of 19 February 2016 (Federal Law Gazette I p. 254).

requirements are also laid down for the responsible shift personnel, consisting of shift supervisor, deputy shift supervisor and reactor operator. Furthermore, for this group of staff, basic requirements apply for the examination of the technical qualification. These are specified in the guideline relating to the contents of the examination of the technical qualification of the responsible shift personnel. In 2013, this guideline was supplemented by the adaptation of the rules and regulations on the qualification of responsible nuclear power plant personnel at nuclear power plants without authorisation for power operation.

- Guideline relating to the assurance of the necessary knowledge of persons otherwise engaged in the operation of nuclear power plants:
  In addition to the guideline concerning the proof of the technical qualification of nuclear power plant personnel, this one applies to the group of staff who has to carry out instructions and decisions of the responsible personnel. This also applies to external personnel, for which the necessary knowledge, requirements on education and introduction are regulated in this guideline. Furthermore, this guideline describes in which way the proof of knowledge is to be provided and what exceptions are included.
- Guideline for the maintenance of technical qualification of responsible nuclear power plant personnel:
  This guideline lays down the requirements for the programmes for the maintenance of the technical qualification of responsible shift personnel and the requirements for the measures to maintain the technical qualification of responsible staff.
- Guideline relating to the contents of the examination of the technical qualification of the responsible shift personnel:
  This guideline lays down the content of the examination of technical qualification of the responsible staff and the responsible shift personnel in detail. The technical qualification examination consists of an oral and a written part and covers both nuclear basic knowledge as well as installation-specific knowledge.
- Guideline relating to the necessary technical qualification in the field of radiation protection (guideline for the technical qualification according to the Radiation Protection Ordinance):
  This guideline lays down the requirements relating to the technical qualification of radiation protection supervisors or radiation protection officers. These include the scope of the technical qualification, the acquisition and certification of the technical qualification, and the recognition of courses and further qualification measures.
- Guideline relating to the technical qualification of radiation protection executives at installations for the fission of nuclear fuel:
  Here, the requirements laid down in the guideline for the technical qualification according to the Radiation Protection Ordinance (StrlSchV) are supplemented for the radiation protection executives in nuclear installations. This applies to the scope of the technical qualification as well as to the acquisition and certification of the technical qualification.

Responsible staff

Based on the guideline concerning the proof of the technical qualification of nuclear power plant personnel, the responsible staff receive the necessary knowledge for the safe operation of the nuclear installation as part of education and training. In addition to the other persons of the responsible staff defined in this guideline, the group of the responsible shift personnel is to be mentioned in particular which is composed of the shift supervisor, the deputy shift supervisor and the reactor operator. The necessary qualifications that must be proven comprise the following:

- **For shift supervisors:**
  Degree in mathematics, sciences or technology in the relevant discipline.

- **For shift supervisor deputies:**
  At least a completed vocational training as technician or a master's certificate in the relevant discipline.
- **For reactor operators:**
  Completed vocational training as technician or a master's certificate, at least, however, a journeyman's certificate or a completed vocational training as a certified power plant operator in the field of nuclear technology,
- the necessary basic knowledge in physics, technology and law,
- the necessary knowledge concerning the design and behaviour of the installation as well as emergency preparedness measures and relevant standards and guidelines,
- the ability to operate the installation safely also in the event of incidents and accidents (for the reactor operator: safe operation of the installation from the control room or the remote shutdown station),
- at least three years of practical experience in the installation (two years for reactor operators), including at least six months as a reactor operator (not applicable to reactor operators, instead of it six months of practical experience in the shift operation of the nuclear installation), and
- a simulator training course of seven weeks (boiling water reactor (BWR)) or eight weeks (pressurised water reactor (PWR)).

Following the training it is ensured by examining the qualification that the knowledge acquired meets the requirements.

Through various measures as part of technical qualification maintenance it is ensured that the skills and knowledge of responsible shift personnel is maintained also beyond the initial training phase. This includes, among other things, theoretical and practical retraining, simulator courses and seminars. When planning these measures, new findings and changed or additional requirements are always to be taken into account. The operating experience, both from the own installation and, as far as applicable, from other nuclear installations, is also to be dealt with. Proof of the performance of these measures is to be supplied to the nuclear licensing and supervisory authority on an annual basis.

Other staff

The requirements defined in the guideline relating to the assurance of the necessary knowledge of persons otherwise engaged in the operation of nuclear power plants are based on the assignment to knowledge groups and knowledge levels, depending on the field of activities. These are divided into four knowledge groups (radiation protection, fire protection, industrial safety and plant organisational structures and procedures), each with three knowledge levels. Based on the field of activity, each person working in the power plant is assigned to a corresponding level in all four groups. By means of training courses, the licence holder has to ensure that the persons receive the relevant skills and knowledge. For external personnel, these requirements may be less stringent if they will have a supervisor during their work. Checking the external personnel is the responsibility of the licence holder (→ Article 13).

Simulators

Installation-specific full-scope simulators are available for German nuclear installations with authorisation for power operation at the Kraftwerksschule Essen. Simulator training is an essential part of the acquisition and maintenance of technical qualification. Training is regularly adapted to new findings and technical facts. The training courses deal, among others, also with methods for coping with stress situations and communication. Particular attention is paid to the feedback of operating experience.

The simulators reproduce the referenced nuclear installation in appearance and also in its technical, physical and temporal behaviour. The operating staff encounter the same working conditions and requirements as they would or could occur when operating and monitoring the real installation.

The training programmes cover normal operation, operational disturbances as well as all accidents and selected emergencies. Training places equal emphasis on operating and understanding the technology as well as on human performance in the team.

Knowledge maintenance

Also, in view of the remaining operating lives of the nuclear installations until 2022 and the subsequent decommissioning operation it is still necessary to maintain the acquired specialist knowledge and to further develop the state of the art in science and technology in order to continue to maintain and improve the current level of safety of the nuclear installations. For this purpose, maintenance and development of competence in nuclear technology is ensured i.a. through the project-based funding of research projects in the field of nuclear safety and waste management research of the Federal Ministry for Economic Affairs and Energy (BMWi) and the recruitment of young scientists in nuclear technology. The Federal Ministry of Education and Research (BMBF) supports projects in nuclear safety and waste management research for the promotion of young scientists and maintenance of competence within the framework of project funding and the so-called institutional funding of the Helmholtz-Gemeinschaft (HGF) and thus contributes substantially to maintaining competence. In addition to general research funding, departmental research is another instrument. The aim of departmental research is to gain scientific knowledge for the proper fulfilment of departmental tasks. It thus also contributes to the general gain in knowledge. The research framework of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in the field of nuclear safety and radiation protection is concretised annually by individual research and development projects. These are part of the departmental research plan on the basis of which the research funds are managed.

Supervision

As part of the licensing and supervisory procedure, the competent nuclear licensing and supervisory authority has to verify compliance with all guidelines listed in this article. This is done on the basis of regular proofs to be furnished by the licence holder. Within the framework of the technical qualification examinations, this is ensured by the participation of a representative of the nuclear licensing and supervisory authority in the examination board as assessor. Through discussions with the licence holder and controls in the installation, individual aspects of recruitment, personnel development and staffing are assessed and evaluated. Furthermore, the licence holder submits proofs of training of the responsible staff and his three-year programme on the maintenance of technical qualification of the responsible shift personnel to the competent nuclear licensing and supervisory authority of the *Land*. In addition, a significant change in the number of staff employed also requires review and approval by the competent nuclear licensing and supervisory authority of the *Land*.

Within the framework of their competence, the nuclear supervisory authorities of the *Länder* also supervise the assurance of the necessary knowledge of the responsible staff and persons otherwise engaged in the nuclear installations (→ Article 12). Since the 13th AtG amendment, increased attention is also paid to the measures taken by the licence holders to prevent a loss of motivation and know-how in nuclear supervisory procedures of the *Länder*.

12 Human factors

ARTICLE 12 HUMAN FACTORS

Each Contracting Party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

Legal and regulatory requirements

According to § 7(2)1 of the Atomic Energy Act (AtG), a licence to operate a nuclear installation may only be granted if there are no doubts about the trustworthiness of the persons responsible and if these have the requisite technical qualification.

The substatutory "Safety Requirements for Nuclear Power Plants" stipulates that the licence holder of a nuclear installation has to ensure the development, introduction and continual improvement of an integrated process-oriented management system. Furthermore, operating principles have to be realised to promote safety. Among these general requirements are i.a.

- maintenance- and inspection-friendly design of the systems and plant components, with special consideration of the exposure of the personnel,
- ergonomic design of the workplaces,
- reliable monitoring of the operating conditions that are relevant in the respective operating phase.

In addition, the "Safety Requirements for Nuclear Power Plants" make ergonomic requirements which have to be considered in the design of measures and activities as a prerequisite for the safety-related necessary and reliable human performance.

Requirements which also take into account reliable and safety-oriented human performance are specified i.a. by the following KTA safety standards:

- KTA safety standards 1201 "Requirements for the Operating Manual", 1202 "Requirements for the Testing Manual" and 1203 "Requirements for the Emergency Manual" contain the requirements for the respective manuals (→ Article 19). These also include requirements for the content of the instructions and for the ergonomic representation of information, especially if it is not available in paper form.
- KTA safety standards 1301.1 and 1301.2 "Radiation Protection Considerations for Plant Personnel in the Design and Operation of Nuclear Power Plants" (Part 1: "Design" and Part 2 "Operation") deal in general with the protection of workers against ionising radiation (→ Article 15) during operation. This also includes the consideration of ergonomic aspects, the support of the tasks by work equipment to be provided and training measures in order to keep working times as short as possible.
- KTA safety standard 1402 "Integrated Management System for the Safe Operation of Nuclear Power Plants" defines in detail the components of an integrated management system (IMS) (→ Article 10), requiring i.a. that safety culture is to be promoted and that all activities that have a direct or indirect influence on the safe operation of a nuclear installation be identified, described, coordinated and continuously reviewed and improved. Since safe operation also depends to a large extent on human and organisational factors, it follows that these must be included in the continuous review and improvement process as well as in the technical processes. The management system shall integrate requirements on the system of man, technology and organisation (MTO) and thus on human factors (KTA 1402, 3.5). Sufficient human and financial resources shall also be provided for the operation of the plant and the maintenance of the core competences in order to maintain and improve the technical, organisational

and administrative safety level of the installation (KTA 1402, 4.1.5). With regard to the number of staff and staff qualification, sufficient capacities shall also be provided in the long term (KTA 1402, 4.2.5.1). In the case of organisational changes, accompanying measures shall be specified to ensure the effectiveness of the changes, e.g. communication and training of staff (KTA 1402, 5.5).

- Safety standard KTA 3501 “Reactor Protection System and Monitoring Equipment of the Safety System” contains the requirement for the safety system that human factors are also to be considered in connection with accident control. Section 4.1.10 (2) stipulates e.g. the following: “Preventive measures shall be taken to avoid faults from errors and negligence during the performance of necessary manual actions related to the operation and maintenance of Cat A equipment (…) and measures shall be considered for limiting the effects of failures. (…) In this context, suitable measures are, e.g., (…) clearly structured, ergonomic arrangement of the components of the safety system.”
- Safety standard KTA 3904 “Control Room, Remote Shutdown Station and Local Control Stations in Nuclear Power Plants” contains requirements for the control room, remote shutdown station and local control stations of a nuclear installation. This concerns e.g. their design according to ergonomic aspects in order to prevent human error. Appendix A of this safety standard specifies how the ergonomic design of the main control room, remote shutdown station and local control stations is to be methodically approached. Appendix B of this safety standard tables the staffing of the main control room, remote shutdown station and local control stations with the number of persons depending on the mode of operation.
- Further KTA safety standards contain requirements for ergonomic aspects insofar as they are relevant for the scope of application of the relevant safety standard. Examples are: preparation and keeping freely accessible the necessary staging and free movement areas for fire engines as well as access routes and entry points for fire brigades, fire-fighting and rescue operations (safety standard KTA 2101.1, “Fire Protection in Nuclear Power Plants Part 1: Basic Requirements”), support of reliable internal and external communication by appropriate design of the communication means as well as the reliable perception of alarms by appropriate design of the alarm signals (safety standard KTA 3901, “Communication Means for Nuclear Power Plants”), support, organisation and performance of transports and precautions against possible human errors (safety standard KTA 3903, “Inspection, Testing and Operation of Lifting Equipment in Nuclear Power Plants”).

Furthermore, a recommendation was issued by the Reactor Safety Commission (RSK) concerning the human factor in nuclear installations:

- Requirements on the determination of the minimum shift staffing at nuclear power plants to ensure safe operational management[11]
  In order to regulate the minimum shift staffing during power operation, deliberations were made in this document on how this should be specified. It is recommended that the minimum shift staffing should be chosen such that an event on level of defence 3 can be controlled. The resulting number of staff is listed in detail.

The “Guide to the decommissioning, the safe enclosure and the dismantling of facilities or parts thereof as defined in § 7 of the Atomic Energy Act” contains the requirement that the “applicant/operator must ensure that an adequate number of staff with the required qualification and knowledge is available in all phases and periods of the decommissioning procedure until release from regulatory control. (...) According to § 7(2)1 AtG, the persons who are responsible must have the necessary technical qualification, and the organisational structures necessary to ensure safety must be in place.” (Section 3.7).

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[11] RSK recommendation, “Anforderungen an die Bestimmung der Mindestschichtbesetzung in Kernkraftwerken zur Gewährleistung einer sicheren Betriebsführung”, adopted at the 417th meeting of the RSK on 18 June 2009

Consideration of human and organisational factors in the design and modification of nuclear installations

German nuclear installations are highly automated. This includes the automatic activation of many complex switching operations in addition to the extensive instrumentation and control for normal operation. This helps to relieve the personnel from routine actions and to focus on the monitoring of the safety-relevant processes and process parameters. The workplaces necessary for monitoring and for switching actions are, as demanded by the national nuclear regulations, designed according to ergonomic aspects. The routes to the places where work is to be carried out are also chosen and designed in such a way as to protect as far as possible against exposure and risks of accidents at work, e.g. as a result of inadequate lighting or the risk of slipping. The reactor protection system is designed such that within the first 30 minutes after the onset of an accident there is no need for any manual action. In case of any anticipated operational occurrences or design basis accidents, this concept aims to ensure sufficient time to diagnose the situation and take appropriate actions. Manual actions may still be performed by the shift personnel within the specified 30 minutes if a sound diagnosis of the accident is given and if the manual actions are clearly safety-oriented (e.g. if they lead to an end or mitigation of the accident sequence). The emergency manual (NHB) – which is applicable in the case of design extension conditions – is also designed with ergonomic aspects in view. The structure has been chosen such that the prescribed measures can also be performed under the special conditions of the emergency situation (e.g. by providing suitable take-away copies for activities outside the control room or remote shutdown station).

Computerised information systems support the shift personnel in all nuclear installations. With regard to maintenance, especially as concerns in-service inspections, extensive technical measures are provided to prevent human errors or to minimise their effects. These measures range from permanently installed and unambiguously identifiable test equipment, test computers and test instructions to the automatic resetting of safety systems in the event of their actuation by the reactor protection system in the course of an in-service inspection.

To protect the operating staff from ionising radiation, corresponding radiation protection measures are provided in all nuclear installations. These also consider ergonomic aspects so that working times during maintenance are kept as short as possible and that consequently exposure is kept as low as possible. One of these measures is also the quick and correct registration of the actual state of the installation and the systems.

In all nuclear installations, procedures are defined for the planning and performance of maintenance, servicing and modifications with the aim of contributing to ensuring the safety of the installation and promoting occupational safety while taking safety of the installation into account. Installation modifications must take into account the legal and regulatory requirements for ergonomic design and precautions against human error.

In the case of organisational changes, in addition to the changes, accompanying measures are planned, implemented and evaluated within the framework of a change management with which the staff are informed about the upcoming changes on the one hand. On the other hand, the accompanying measures are intended to maintain know-how and motivation for the new tasks arising from the change from power operation to decommissioning.

Organisation of the feedback of experience regarding human and organisational factors

The licence holders of nuclear installations apply comprehensive measures to avoid failures due to human actions or organisational shortcomings. This includes not only taking appropriate measures to prevent the negative effects of failures (defence in depth) but also identifying and analysing these at an early stage before they occur and eliminating the causes of the potential failures by means of improvement measures to avoid recurrence of the same failure in the future.

The most important source of knowledge for measures here is the feedback of experience from internal and external operating experience. This is organised within the framework of the IMS (→ Articles 10 and 13) and is characterised by a systematic exchange of experience on safety-relevant information and events. In order to be able to carry out a systematic exchange of experience, it is necessary to guarantee good communication between all levels of the operating organisation. In order to obtain additional benefit from external experience, the licence holders of German nuclear installations cultivate a lively and systematic exchange of experience among each other and with international organisations such as WANO (World Association of Nuclear Operators).

Selected human errors are evaluated within the framework of an integrated event analysis (→ Articles 6 and 19). The aim of this analysis is to learn from operating experience gained and to derive safety-related improvements. To achieve this, the areas of man, technology and organisation are treated equally. The analysis also looks at weak points and failure sources at the interfaces of the three areas. This holistic approach makes it possible in principle to identify the factors that have led to an event. On this basis, measures are then developed to eliminate identified sources of error. In 2000, the licence holders began developing the VGB Guideline "Integrated event analysis", which was presented for the first time in 2003. Since then, it has been updated several times.

The operating experience gained from the analysis of safety-relevant events is communicated to the licence holders in the case of events with relevance for other installations via the competent nuclear licensing and supervisory authority of the *Land* in the form of an information notice (WLN) (→ Article 19). The licence holders then prepare a feedback regarding the contents of the WLN, especially also with a view to the applicability to their own nuclear installations. Within the framework of these mechanisms, experience concerning human and organisational factors are also passed on. This experience is used, e.g., for training within the framework of maintaining the technical knowledge of the operating staff or within the framework of specific training measures to ensure safety-oriented behaviour (e.g. human performance optimisation (HPO) training). Should any organisational deficiencies come to light in the course of the analysis, the processes have to be improved within the framework of the IMS.

In addition, the RSK prepares generic recommendations on the basis of experience and findings also with regard to human factors. These recommendations are published and considered by the nuclear licensing and supervisory authorities of the *Länder*.

Self-assessment of management and organisation of the licence holders

The management and organisation of the licence holders of nuclear installations are based on a statutory IMS whose requirements are described in the "Safety Requirements for Nuclear Power Plants" and in safety standard KTA 1402 "Integrated Management Systems for the Safe Operation of Nuclear Power Plants" (→ Article 10). These stipulate i.a. continuous monitoring, assessment and improvement of all processes. In this respect, the fulfilment of the process targets, process performance, the compliance with the process specifications and the possibilities of improvements are used as indicators for the assessment of the processes. These are carried out within the framework of reviews with national and international experts. On the other hand, audits and independent process assessments are also carried out by management staff of the nuclear installation. Based on the information gathered, a data analysis is carried out to assess the effectiveness and quality of the management system. If deviations or inadequacies are identified in the course of this assessment, appropriate improvement measures are defined, the effectiveness of which must in turn be checked using suitable methods.

Regulatory review

The implementation of the requirements mentioned is reviewed by the competent nuclear licensing and supervisory authority of the *Land* through various supervisory activities (e.g. on-site supervisory inspections on the integrated event analysis and on organisational topics). This is done in the context of the granting of the nuclear licence for the construction and operation of the nuclear installations in accordance with the then applicable requirements of the national nuclear rules and regulations. For this purpose, the safety demonstrations provided by the applicants, e.g. by the licence holders, were subjected to comprehensive reviews by the competent nuclear licensing and supervisory authority. Any later modifications to safety-relevant plant components and written operating rules (e.g. the operating manual (BHB) or test manual) require licensing (or, in the case of minor changes, approval or information) by the competent licensing and supervisory authority of the *Land*. Modifications, including organisational changes, are thus subject to a comprehensive review within the framework of the modification procedure. In the assessment of reportable and other events, the nuclear licensing and supervisory authority also considers the contributing factors in the area of “man and organisation”.

13 Quality assurance

ARTICLE 13 QUALITY ASSURANCE

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

Legal and regulatory requirements

§ 7c(2) of the Atomic Energy Act (AtG) obliges the licence holder i.a. to establish and apply a management system.

The basic requirement with regard to systematic quality assurance at nuclear installations can be found in the “Safety Requirements for Nuclear Power Plants”. There, the implementation of an integrated management system (IMS) is required for all nuclear installations. Its objectives and requirements also include quality assurance. This is specified within the framework of the national nuclear rules and regulations, especially in the KTA safety standards, as follows:

- Safety standard KTA 1401 “General Requirements Regarding Quality Assurance”:
  This KTA safety standard explains and defines i.a. the basic requirements for quality assurance, its organisation and planning as well as design. Safety standard KTA 1401 was revised with regard to the new KTA 1402 and entered into force in November 2013. Among other things, process-related requirements, such as for the area “Operation”, have been moved to safety standard KTA 1402, and systematic quality management is also required from subcontractors. Another revision took place in 2017.
- Safety standard KTA 1402 “Integrated Management System for the Safe Operation of Nuclear Power Plants”:
  This KTA safety standard contains requirements for an IMS. These requirements ensure that all safety-relevant activities and processes are identified and described within the framework of a management system. Full and complete recording and description of all work procedures and activities as interlinked processes and their identifiable dependencies facilitates review and assessment and enables the continuous improvement of the safety of the installation as safety performance of the comprehensively described organisation and its functioning. KTA 1402 was revised in 2017. It now contains i.a. requirements for the management of the installation to carry out a regular self-assessment of the safety culture and an independent assessment of the safety culture and to implement improvement measures to maintain and continuously improve a high level of safety culture. Furthermore, the effectiveness of the measures derived from the internal experience feedback is explicitly required to be reviewed.

In addition, DIN EN ISO 9001:2015[12] places basic requirements on quality management. This standard is applied in many sectors of the industry and is used by the licence holders to ensure the quality of products of contractors and subcontractors.

Elements of the integrated management system

The IMS defined in safety standard KTA 1402 is based on a process-oriented approach. All activities relevant for operation are to be identified and, if having a direct or indirect influence on safety, are to be described by processes. In addition, continuous review and improvement of processes and the IMS is ensured by the consistent use of the Plan-Do-Check-Act cycle. All processes are documented in a standardised and consistent manner in order to be able to understand the process and the decisions taken at any time.

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[12] DIN EN ISO 9001:2015-11, Quality management systems – Requirements

The overall objective of the IMS is, in addition to nuclear safety, to also integrate requirements from other company perspectives (e.g. economic aspects) into the management system. The IMS is to ensure that in the case of competing requirements and objectives for the installation, those of nuclear safety are given priority according to their significance (→ Article 10).

Each licence holder already had to meet individual specific quality assurance requirements on the basis of the provisions of the “Safety Criteria for Nuclear Power Plants” of 1977. In 2012, the safety criteria were replaced by the newly developed “Safety Requirements for Nuclear Power Plants”. Here, the specific requirements for quality assurance were also supplemented by an IMS. In addition, safety standard KTA 1401 was revised and nuclear safety standard KTA 1402 newly created to provide specifications in the fields of quality management and IMS. The concrete implementation of the requirements from “Safety Requirements for Nuclear Power Plants” and the safety standards 1401 and 1402 is described in plant-specific documents. These documents further specify how and by whom the requirements necessary for safety are established and fulfilled, and how and by whom their fulfilment is verified. These include descriptions of procedures for the initiation of corrective measures in case of non-compliance with the requirements. Furthermore, the structure of the organisation implemented for quality assurance is described and reference is made to work procedures for the performance of quality assurance.

Audit programmes of the licence holder

Quality assurance is carried out by the licence holder within the framework of his responsibility for the safety of the installation.

With the introduction of DIN EN ISO 9001:2000 (now DIN EN ISO 9001:2015) and the related discussion about management systems, e.g. the safety management system, the licence holders further developed quality assurance to a process-oriented and thus adaptive quality management. Some nuclear installations have their quality management system already certified according to DIN EN ISO 9001.

In exercising their responsibility for safe operation, the licence holders regularly review their management systems by own internal reviews. These reviews are typically applied for management systems, processes or products, including maintenance work.

Audit programmes of the licence holder for manufacturers and suppliers

For supplies and services, contractors and their subcontractors must plan and carry out quality assurance in accordance with the requirements of the quality system of the nuclear installation. The licence holder checks the contractors in accordance with safety standard KTA 1401. For each subcontract, a contractor assessment is performed.

The data and information about the contractors are stored in a central database of VGB and are available for each nuclear installation. Any identified gaps and deficiencies are immediately communicated and corrective actions are taken.

Regulatory review

Within the framework of their supervisory activities, the nuclear licensing and supervisory authorities pursue and gather information about the following topics of the management system:

- Results of the management review
- Results of the internal audits
- Evaluation of indicators (→ Article 10)
- Implementation of measures derived

- Further development of the integrated management systems
- Promotion of safety culture (integral part of the management system)

On the basis of findings obtained, the *Land* authority competent for licensing and supervision generally verifies the effective implementation of the quality assurance system. Moreover, the supervisory authority controls the results of the reviews performed by the licence holder and the implementation of measures derived from it within the framework of on-site inspections. This also includes inspections of the production process of technical components at the manufacturers and suppliers of the licence holder. The overall organisational responsibility for an effective management system remains with the licence holder.

Ensuring product quality in the long term

The quality of the required safety-related components of the German nuclear installations is regulated by long-term supply contracts with the component manufacturers. The supply of quality-assured parts can thereby be planned over periods of several years and is supported by the close cooperation between the licence holders themselves and within the framework of the VGB activities for nuclear procurement. In addition, all licence holders have well-equipped local workshops or contracts with such workshops which can manufacture selected parts themselves or carry out repairs. Significant changes, for example regarding the range of products or in the manufacturing market, can be recognised in time by further measures and processes and alternative solutions applied. These include for example, besides the above-mentioned audit programmes and contractor assessments, targeted provision and adaptation of technical specifications and testing requirements, additional contractor training, continuous feedback of experience, suppliers market assessments, strategy discussions with manufacturers and suppliers for the provision of services and supply of spare parts until the end of the operating life, as well as an optimised management for spare, stand-by and wear parts in stockkeeping, also in connection with decommissioning.

Thus, the requirements of safety standard KTA 1401, revised in 2017, can also be fulfilled in the long term, according to which the client shall ensure, when re-ordering series-produced items, that these have not been changed with regard to the original order or, in the case of changes, a renewed qualification may be required. The prerequisites for the supply with quality-assured products have thus also been created with regard to the remaining operating lives, laid down by law, until 2022.

14 Assessment and Verification of Safety

ARTICLE 14 ASSESSMENT AND VERIFICATION OF SAFETY

Each Contracting Party shall take the appropriate steps to ensure that:

i) comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body;

ii) verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.

14 (i) Assessment of safety

Requirements for safety assessments in licensing and supervisory procedures

According to § 7(2) of the Atomic Energy Act (AtG), a licence for major modifications of nuclear installations or their operation may only be granted if

1. there are no known facts giving rise to doubts as to the reliability of the applicant and of persons responsible for the construction and management of the installation and the supervision of its operation, and the persons responsible for the construction and management of the installation and the supervision of its operation have the requisite qualification,
2. it is assured that the persons who are otherwise engaged in the operation of the installation have the necessary knowledge concerning the safe operation of the installation, the possible hazards and the protective measures to be taken,
3. the precautions have been taken as are necessary in the light of the state of the art in science and technology to prevent damage resulting from the construction and operation of the installation,
4. the necessary financial security has been provided to comply with legal liability obligations to pay compensation for damage,
5. the necessary protection has been provided against disruptive action or other interference by third parties,
6. the choice of the site of the installation does not conflict with overriding public interests, in particular in view of its environmental impacts.

When performing comprehensive and systematic safety assessments in licensing and supervisory procedures, the following is to be taken into account i.a.: the “List of Contents and Structure of a Standard Safety Analysis Report for Nuclear Power Plants with Pressurized Water Reactor or Boiling Water Reactor” (List of Contents), the “Compilation of Information Required for Review Purposes under Licensing and Supervisory Procedures for Nuclear Power Plants”, the “Guides for the Periodic Safety Review of Nuclear Power Plants”, and, for specific technical aspects and occasions, in the various regulations of the substatutory guidance instruments such as the “Safety Requirements for Nuclear Power Plants”, their “Interpretations” and the safety standards of the Nuclear Safety Standards Commission (KTA) (→ Article 7 (2i)).

Requirements on the documentation for safety assessments in licensing and supervisory procedures

When applying for a licence for the construction, operation and for essential modifications of a nuclear power plant or its operation, it has to be demonstrated in detail to the competent nuclear licensing and supervisory authority that the licence prerequisites stated in § 7(2) AtG (→ Article 7 (2ii)) are fulfilled. § 3 of the Nuclear Licensing Procedure Ordinance (AtVfV) defines the type and extent of documents to be submitted with an application. This includes in particular, within the framework of construction and commissioning, a safety analysis report which allows a conclusion as to whether the licensing prerequisites have been met. Thus, the safety analysis report is the basis for the safety assessment of the nuclear installation.

According to the List of Contents, the safety analysis report has to describe the actual and potential impacts of the installations and the precautionary measures provided to be taken into consideration for the decision on the licence application. In this respect, third parties shall have the possibility to assess whether their rights could be violated by the nuclear installation and the impacts associated with its operation. The safety analysis report has to describe the safety concept, all hazards associated with the nuclear installation and the measures important to safety, systems and equipment provided, including the design features important to safety.

The above-mentioned “List of Contents” provides a standardised form for safety analysis reports of nuclear installations with PWRs and BWRs, specifying a detailed outline of the subjects and giving additional information on the contents. The main items of the safety analysis report are

- site,
- power plant and protective measures against internal and external hazards,
- organisational structure and responsibilities,
- radioactive materials and the corresponding physical protection measures,
- power plant operation, and
- design basis accident analyses.

Except for the conditions and limits of safe operation and emergency preparedness, the safety analysis report thus covers all topic areas demanded by the IAEA Safety Standard GS-G-4.1. In Germany, the conditions and limits of safe operation are part of the operating manual (BHB). The emergency organisation is described in the emergency manual (NHB), which is required according to safety standard KTA 1203 “Requirements for the Emergency Manual”. Furthermore, information on the future decommissioning of the nuclear installation is also required in the safety analysis report. Details on precautions against disruptive action or other interference by third parties are required as part of a separate physical protection report, which is classified as confidential in accordance with classified information instructions.

Together with the application for the operation of the installation, the safety specifications required by the AtVfV and described in the “Guidelines Concerning the Requirements for Safety Specifications for Nuclear Power Plants” as well as in safety standard KTA 1201 “Requirements for the Operating Manual” have to be presented. They comprise in particular details on

- the organisational structure,
- requirements important to safety,
- reactor protection system limit values,
- technical drawings of important components including operating parameters, preceding limits, actuating limits, and design basis values,

- the general in-service inspection plan for systems and components important to safety and
- the treatment of reportable events.

The safety specifications as well as the associated inspections of safety-relevant plant components are described in more detail in Article 19 (ii). All documents prepared or to be prepared for verification purposes, including the expert analysis reports and assessments by the licensing and supervisory authority, have to be compiled systematically in a safety documentation. The licence holder has to prepare the safety documentation on the basis of the guidelines regarding the fundamental principles and requirements and keep it up to date. The safety documentation includes all technical documents required in terms of the AtG for verifications in nuclear licensing and supervisory procedures. These include e.g.

- documents on the provisions governing the design, construction, operation and testing of the nuclear installation,
- documents pertaining to safety-related purposes and the mode of functioning of safety-related systems and equipment,
- specifications regarding design, materials, construction and testing as well as specifications concerning maintenance and repairs,
- documents on the results of safety-related measurements and tests including the results from non-destructive and destructive material testing,
- documents on the fulfilment of safety-related specifications, e.g. verification calculations and design plans or drawings,
- operating records that are significant from a safety-related point of view,
- documents pertaining to the radiation protection of the personnel and the environment, and
- other documents proving the fulfilment of safety-related specifications, requirements and directives.

In compliance with the licensing prerequisites, the licence holder has to perform the safety assessments of nuclear installations with consideration of operating experience and according to the precautions to be taken in the light of the state of the art in science and technology. If required, report is to be made on the results of these assessments and resulting measures in accordance with the requirements of the licence and the specifications in the BHB.

Safety assessments in the supervisory procedure

Safety assessments are submitted to the supervisory authority upon special request, in the course of licence applications for modifications pursuant to § 7 AtG or modifications subject to approval within the framework of supervision according to § 19 AtG (→ Article 7 (2ii)).

The Safety Review (SÜ) required according to § 19a AtG is dealt with in detail in the following section.

Safety assessments only taking into consideration a specific section of the nuclear installation are e.g. the analyses to be performed for the safety demonstration on the new reactor core before refuelling. The scope and content of these analyses are regulated in the respective licences. In these analyses, the calculation of essential physical parameters and the fulfilment of the safety-related boundary conditions are demonstrated to the supervisory authority with regard to their compliance with the protection goals (→ Article 18 (i)).

Safety assessments are also submitted to the supervisory authority in the course of licence applications for modifications of the plant or its operation pursuant to § 7 AtG or modifications subject to approval within the framework of supervision according to § 19 AtG. The licensing procedure for modifications pursuant to § 7 AtG is basically performed according to the same regulations already described for the granting of a construction licence. This also applies to the documents to be submitted and the safety assessment based on them (→ Article 7 (2ii)). As regards modifications of the nuclear installation or its operation that are not subject to licensing pursuant to § 7 AtG due the negligibility of their impact on safety, these are regulated in Germany in the different supervisory procedures of the *Länder*. These regulations specify which types of modifications require prior approval by the licensing and supervisory authority and of which modifications the licensing and supervisory authority only has to be notified.

After any safety-relevant event at a nuclear installation, the licensing and supervisory authority may require safety assessments, in particular if measures against a recurrence or for an improvement of safety have to be taken. Safety assessments may also be required in case of any safety-relevant event at other nuclear installations with regard to their possible applicability to the installation in question. New findings from plant operation or the latest state of the art in science and technology may require that safety demonstrations that have already been provided need to be updated.

Decennial Safety Review (SÜ)

Since the beginning of the 1990s, SÜs have been carried out every ten years according to standardised national criteria. They consist of a deterministic safety status analysis, a probabilistic safety analysis (PSA) and a deterministic analysis of the physical protection of the installation. The SÜ supplements the continuous review process which is part of regulatory supervision.

The SÜ results have to be submitted to the competent licensing and supervisory authority of the *Land* and are assessed by independent experts who act by order of the licensing and supervisory authority.

Since the amendment of the AtG in April 2002, the performance of SÜs every ten years has been mandatory, with the date of the first SÜ laid down for every installation. The obligation to present the SÜ results is lifted if the licence holder makes the binding declaration to the licensing and supervisory authority that he is definitively going to terminate power operation at the installation no later than three years after the final date for submission of the SÜ mentioned in the AtG. During the current review period (2017 - 2019), an SÜ took place at the nuclear installation Gundremmingen, Unit C, which has now been completed. The results as well as the results of the SÜ of the nuclear installation Brokdorf already completed in 2016 are currently available for assessment by the competent nuclear licensing and supervisory authority (→ Table 14-1).

For the nuclear installations in post-operation, the General Committee of the *Länder* Committee for Nuclear Energy (LAA) has decided that the licence holder has to prepare a safety analysis for the post-operational phase. Details on this were set out in a checklist for the performance of an assessment of the current safety status of the installation for the post-operational phase.

Table 14-1 Safety Reviews of the nuclear installations

Installation		Type	Last date	Next date
1	Biblis A	PWR	31.12.2001 (31.12.2011*)	--
2	Biblis B	PWR	31.12.2000 (31.12.2010*)	--
3	Neckarwestheim I	PWR	31.12.2007	--
4	Brunsbüttel	BWR	30.06.2001 (30.06.2011*)	--
5	Isar 1	BWR	31.12.2004	--
6	Unterweser	PWR	31.12.2001 (31.12.2011*)	--
7	Philippsburg 1	BWR	31.08.2005	--
8	Grafenrheinfeld	PWR	31.10.2008	--
9	Krümmel	BWR	30.06.2008	--
10	Gundremmingen B	BWR	31.12.2007	--
11	Grohnde	PWR	31.12.2010	**
12	Gundremmingen C	BWR	31.12.2017	--
13	Philippsburg 2	PWR	31.10.2008	**
14	Brokdorf	PWR	31.10.2016	--
15	Isar 2	PWR	31.12.2009	**
16	Emsland	PWR	31.12.2009	**
17	Neckarwestheim II	PWR	31.12.2009	**

Shaded fields denote the nuclear installations that have been shut down.
* Safety Review performed, no evaluation
** No future Safety Review required according to § 19a(2) AtG
(Power operation will cease no later than three years after the ten-year review interval).

For the results achieved so far, it can be stated that on the basis of the analyses performed, it was demonstrated that the German nuclear installations fulfil the safety requirements that are necessary to comply with the protection goals, referred to as “fundamental safety functions” in the IAEA safety standards (→ Article 18 (i)).

Safety assessments performed

Deterministic safety analyses

A focal point of the deterministic safety status analysis is the consideration of the design basis accidents listed in Appendix A of the guide for the safety status analysis and a spectrum of design extension conditions for which it must be demonstrated that accident management measures (→ Article 18 (i)) are in place.

Probabilistic safety analyses (PSAs)

The mid-1970s saw an increasing use of probabilistic safety analyses in Germany in supplement to deterministic safety assessments.

The methods and data to be used for the PSA are described in a guide[13] and in supplementary technical documents (methods and data for probabilistic safety analysis for nuclear power plants[14,15,16]). These were first published in 1996 and updated in 2005 and 2016. The last update contains amendments to the subject areas PSA Level 2, PSA for low-power and shutdown modes, consideration of the human factor in a PSA and PSAs for external hazards which need to be considered in line with the state of the art in science and technology as well as to further methods and data revised in accordance with the state of the art in science and technology and operating experience, including fire events and common cause failures (CCFs). A further supplementary technical document (methods and examples for the probabilistic assessment of safety-relevant issues outside the SÜ[17]) was published in 2018. It contains methodical guidance and recommendations for the implementation of the “Safety Requirements for Nuclear Power Plants” in the field of the application of probabilistic safety analysis methods outside the scope of the SÜ in accordance with § 19a AtG, e.g. in the assessment of modifications of the installation or its mode of operation or of events that have occurred. The central issue of the document is a screening procedure with which the impact of a modification of the installation or its mode of operation on the PSA results can be determined.

Since 1990, the licence holders of the German nuclear installations have performed Level 1 PSAs as part of the SÜ for all German nuclear installations. Level 2 PSAs also exist for all nuclear installations in power operation. The Level 1 PSAs in particular have led to technical and procedural improvements at the nuclear installations.

Since 2005, a Level 1 PSA has comprised

- plant-internal initiating events for all operating states (power operation and low-power and shutdown states),
- for power operation, common-cause initiators such as fire and internal flooding, as well as
- postulated site-specific external hazards such as
  - aircraft crash,
  - blast wave,
  - flooding and
  - site-specific earthquake with an intensity of more than 6 on the Medvedev-Sponheuer-Kárník scale (MSK scale).

A Level 2 PSA has to be performed for internal initiating events for power operating conditions.

Since the 13th AtG amendment no longer requires PSAs to be performed for any of the nuclear installations still in power operation within the framework of the required SÜ, a revision of the PSA Guide is no longer planned.

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13 Bekanntmachung des Leitfadens zur Durchführung der „Sicherheitsüberprüfung gemäß § 19a des Atomgesetzes – Leitfaden Probabilistische Sicherheitsanalyse“ für Kernkraftwerke in der Bundesrepublik Deutschland vom 30. August 2005 (BAnz. 2005, Nr. 207)

14 BfS, Methoden zur probabilistischen Sicherheitsanalyse für Kernkraftwerke, BfS-Schriften; 37/05, ISBN: 3-86509-414-7, August 2005

15 BfS, Methoden zur probabilistischen Sicherheitsanalyse für Kernkraftwerke, BfS-Schriften; 37/05, ISBN: 3-86509-414-5, August 2005

16 BfS, Methoden und Daten zur probabilistischen Sicherheitsanalyse für Kernkraftwerke, BfS-Schriften; 61/16, urn:nbn:de: 0221-2016091314090, September 2016

17 BfE, Methoden und Beispiele für die probabilistische Bewertung sicherheitsrelevanter Fragestellungen außerhalb der SÜ, BfE-Schriften; 03/18, urn:nbn:de:0221-2018013014519, January 2018

Backfitting measures and improvements performed and current activities

Accident mitigation manual

The licence holders of German nuclear installations also developed a generic concept for the management of severe accidents in the form of an accident mitigation manual (HMN) as a supplement to existing NHBs. The strategies and procedures contained in these manuals correspond to the international recommendations on Severe Accident Management Guidelines (SAMGs). This concept has been introduced in all nuclear installations in power operation and is subject to continuous improvement.

Robustness analyses for design extension conditions (cliff edge effects)

Following the Fukushima nuclear accident, the licence holders, exercising their responsibility for nuclear safety, carried out supplementary analyses of the safety precautions in their nuclear installations regarding the robustness and effectiveness of the safety functions that are vital for the prevention and limitation of radioactive releases under design extension conditions. Due to the already existing very high level of protection of the nuclear installations, extremely unlikely scenarios had to be postulated in the robustness analyses in order to highlight safety margins to cliff edge effects for design extension conditions and to identify optimisation potentials. In summary, it was shown that cliff edge effects can generally already highly reliably be prevented with the help of the existing prevention and emergency measures. Additional robustness-increasing measures have further improved robustness in the beyond-design-basis area and in the control of beyond-design-basis events as well as the limitation of their consequences. Further details are given in the published finalised National Action Plan following the Fukushima nuclear accident[18].

Regulatory review

The assessment of the safety of the nuclear installations is continuously reviewed by the competent *Land* authorities within the framework of the nuclear supervisory procedure. If there are any new safety-relevant findings, the need for the implementation of safety-related improvements is examined. This is done by reviewing documents on site at the nuclear installations.

Within the framework of nuclear supervision, the nuclear licensing and supervisory authorities of the *Länder* review the safety assessments carried out by the licence holders both continuously and discontinuously and assess the SÜs in accordance with § 19a AtG. In most cases, the resulting findings on necessary safety improvement measures or backfitting measures are implemented by the licence holders on a voluntary basis. In addition, if generic aspects are concerned, federal oversight is involved.

For the review of the documents submitted by the licence holders, the competent licensing and supervisory authority may consult, in accordance with § 20 AtG, independent authorised experts for the review and assessment of specific technical aspects (→ Article 8 (1)). The general requirements for such expert evaluations are specified in the “Framework Guideline on the Preparation of Expert Opinions in Nuclear Administrative Procedures”.

The experts review the documents submitted by the applicant. Applying assessment criteria on which the review is to be based, they perform independent analyses and calculations, preferably with analytical methods and computer codes different from those used by the applicant. The results are

18 Finalised action plan for the implementation of measures following the reactor accident in Fukushima, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), December 2017, https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/aktionsplan_fukushima_bf.pdf

evaluated. The persons participating in the evaluation are free in their judgement and are mentioned by name to the nuclear licensing and supervisory authority.

14 (ii) Verification of safety

Regulatory requirements

During the operation of the installation, the provisions of the AtG and the statutory ordinances in pursuance thereof have to be complied with. The orders and directions issued hereunder by the nuclear licensing and supervisory authorities and the terms and conditions of the notice granting the licence or general approval as well as any subsequently imposed obligations have to be strictly adhered to.

Detailed requirements for monitoring, in-service inspections and other inspections are to be laid down in the operating manual according to safety standard KTA 1201 “Requirements for the Operating Manual” and in the testing manual according to safety standard KTA 1202 “Requirements for the Testing Manual”.

Regular verification of safety by the licence holder

The responsibility of the licence holder requires that the safety of the installation is in compliance with the provisions of the valid operating licences throughout its entire operating life. In line with the principle of dynamic damage prevention, the necessity and adequacy of improvements has to be checked, especially whenever new safety-relevant findings are available.

The licence holder is legally obliged by the licence to show through regular in-service inspections that the plant characteristics that are relevant for the safety of the installation as well as the safety and barrier functions are given. This is to ensure the quality and effectiveness of the safety-related measures and equipment. The corresponding provisions are contained in the licences, the safety specifications, and the safety documentation. The in-service inspections include functional tests performed to verify functional performance as well as non-destructive tests to verify faultless condition. Moreover, the licence holder plans and performs regular and preventive maintenance of the systems of the installation during operation and evaluates operating experience (→ Article 19 (vii)).

The in-service inspections of systems important to safety are performed in accordance with the requirements specified in the testing manual (→ Article 19 (iii)). Test performance is specified depending on the testability of the respective system function. The objective here is always to perform the test at realistic conditions representing the actual conditions at the time of required functional operation. If important system functions are not directly testable, e.g. integrity at higher levels of pressure and temperature, functional performance is verified indirectly. The specifications for performing the tests are reviewed regularly considering operating experience and new findings from safety research and are adapted if necessary. Table 14-2 lists the nature and average number of the in-service inspections per year with refuelling outage required according to the testing schedule, which is typical of a PWR installation.

Table 14-2 Annual average number of in-service inspections, exemplary for a PWR construction line 3 with one refuelling outage per year

Items	During operation	During outage	Total
Visual and functional tests	2850	1000	3850
Radiation protection	370	20	390
Lifting equipment	70	10	80
Non-destructive tests	10	35	45
Civil engineering	45	15	60
Physical protection	130	5	135
Total	**3475**	**1085**	**4560**

Apart from the in-service inspections of safety-relevant systems and components, the licence holder performs additional inspections under his own responsibility which serve to ensure the availability of the installation.

In addition, the inspections required by the authorities on the basis of conventional regulations are regularly performed by the licence holder (e.g. according to the Ordinance on Industrial Safety and Health).

Ageing management

The necessity of considering ageing effects in nuclear installations has already been recognised in Germany at an early stage. As a consequence, aspects of ageing have been taken into account in the design of German nuclear installations. These include e.g. the careful and appropriate design, manufacturing and commissioning of the installations, including their components and systems, as well as the high quality of the materials used.

Structures, systems and components are monitored for possible ageing effects within the framework of in-service inspections, maintenance and servicing measures. Possible problems are identified in advance and preventive measures are taken in due time. By means of evaluating national and international operating experience, findings from nuclear installations worldwide are continuously incorporated into the measures to control ageing effects at the nuclear installations. In addition, the state of the art in science and technology is evaluated on a regular basis for each installation to be able to take into account new findings on ageing where necessary, and thus to be able to continuously maintain or improve the safety level of the installations.

Within the framework of the nuclear rules and regulations, which provide the assessment criteria for the work of the nuclear supervisory authorities in Germany, a specific standard on ageing management in nuclear power plants was developed (safety standard KTA 1403 “Ageing Management in Nuclear Power Plants”). This KTA safety standard specifies requirements for ageing management which comprise technical and organisational measures for the early detection of ageing phenomena relevant for the safety of a nuclear installation and for the maintenance of the required quality of the structures, systems and components.

The licence holders have set up integrated management systems at the nuclear installations, which also take into account findings on ageing effects. This ensures that ageing management is integrated into the operational processes and that all information required for safe operation is available. The German licence holders discuss the topic of ageing effects and exchange information and experience in their own working groups and expert committees.

The knowledge required for effective ageing management is summarised in a knowledge base and regularly updated so that the identification of safety-related degradation mechanisms is ensured and appropriate measures are derived.

The German nuclear installations are continuously adapted to the state of the art in science and technology as regards ageing management. The annual evaluation of the results of the ageing management programme for the German installations confirms the effectiveness of ageing management in German nuclear installations. The practised procedure ensures that for German nuclear installations the high level of safety during operation is maintained.

The procedure described was presented in detail in the German report on the Topical Peer Review (TPR) of the European Union (EU) on ageing management in nuclear installations and explained using examples. In the report of the European Nuclear Safety Regulator Group (ENSREG) on the results of the Topical Peer Review, two “good practices” and three “good performances” are highlighted for Germany. These concern participation in international cooperation in ageing management, the design of reactor pressure vessels (RPVs) to reduce neutron embrittlement, the consideration of medium influences in fatigue analyses and the test concept for inaccessible pipelines. Potential for improvement was identified in four areas (“areas for improvement”). These are taken into account in the National Action Plan for the TPR.

Measures for internal reviews of the licence holders

World Association of Nuclear Operators (WANO) peer reviews

As members of WANO, the licence holders have committed themselves to have WANO peer reviews carried out at their nuclear installations and their company headquarters, referred to as corporate peer reviews. With the WANO peer reviews, the safety-relevant processes are reviewed and assessed by international experts on a mutual basis. The reviews also serve to identify best practices for operational and management processes from other nuclear installations and to consider the design of the installation when evaluating operating experience. The aim is to improve operational performance in terms of reliability and safety. A review of the implementation of selected optimisation measures is carried out in follow-up reviews.

In Germany, WANO peer reviews were conducted successively for all nuclear installations in operation. From 1997 to 2009, the plants Grohnde (1997 and 2007), Grafenrheinfeld (1999 and 2007), Gundremmingen (2000 and 2007), Neckarwestheim (2001), Brunsbüttel (2001), Isar (2003 and 2009), Emsland (2004), Brokdorf (2005), Biblis (2005), Unterweser (2005), Krümmel (2006 and 2009), and Philippsburg (2009) were subjected to an audit.

For a second cycle for the performance of WANO peer reviews, the following nuclear installations were reviewed again: Emsland (2010), Brunsbüttel (2010), Brokdorf (2011) and Neckarwestheim (2012).

Peer reviews took place for the nuclear installations Grohnde, Gundremmingen and Grafenrheinfeld in the year 2013 and for the Isar site in the year 2014. In 2015, one WANO peer review each was conducted in Philippsburg and Emsland, and in 2016, a WANO peer review was conducted in Brokdorf.

In addition to the WANO peer reviews in the nuclear installations, corporate peer reviews were also conducted at the company headquarters of E.ON Kernkraft GmbH (PreussenElektra GmbH since 2016) in 2009 and RWE Power AG in 2014.

During the review period, WANO peer reviews took place for the nuclear installations Neckarwestheim (GKN II) in 2017 and Isar, Grohnde and Gundremmingen in 2018. WANO follow-up reviews were conducted in Gundremmingen, Unit C and Emsland in 2017 and for Philippsburg (KKP 2) in

2018. Corporate peer reviews were conducted at the company headquarters of PreussenElektra GmbH and EnBW Kernkraftwerk GmbH (EnKK) in 2017 and RWE in 2018.

Further WANO peer reviews are scheduled for the nuclear installations Brokdorf and Emsland in 2019 until the last German nuclear installations will be shut down in 2022.

National peer reviews

Based on the WANO peer reviews, the licence holders of the German nuclear installations carry out national peer reviews. The aim of this initiative – analogous to WANO peer reviews – is to obtain representative statements on the quality of the administrative/operational management at the nuclear installations and, if necessary, implement optimisations. The respective topics on each occasion are chosen by a VGB committee guided by current needs and are then reviewed in all nuclear installations. In 2017, a national peer review was carried out on systematics of the preparation and handling of hazard assessments.

In all, a large number of recommendations were made as a result of the reviews that have led to improvements in the nuclear installations. However, the benefit to the German nuclear installations is generated not just by the teams' recommendations but also by the knowledge gain of the peers from the German nuclear installations who are deployed in large numbers to take part in international WANO peer reviews.

Reviews within the framework of state supervision

The nuclear licensing and supervisory authority monitors and, if necessary, enforces the fulfilment of the licence holder's obligations relating to the licence (§§ 17, 19 AtG).

In addition to the licence holder's own inspections, safety verifications are performed within the framework of state supervision by the competent nuclear licensing and supervisory authorities of the *Länder*. These use various methods to verify whether the licence holders fulfil their obligations. The choice of the applied methods also depends on the plant state, e.g. operation, outage, modification or decommissioning.

Accompanying inspections during construction, commissioning and modification

During the construction and commissioning phases, accompanying inspections were performed by the authorised experts consulted on behalf of the nuclear licensing and supervisory authority in order to monitor compliance with the provisions of the licence provisions and of the supervisory procedure. These accompanying inspections are independent of those carried out by the manufacturer which are intended to verify the values, dimensions or functions specified in the submitted written documents. This includes e.g. the verification of material compositions at the manufacturers', controlling the assembly of components and the performance of functional tests. Similar inspections are also carried out at the construction site. In the commissioning phase, the provisions of the safety specifications for the installation and compliance with the boundary conditions for the accident analysis are checked (→ Article 19 (i)).

Inspections during operation

The nuclear licensing and supervisory authority of the respective *Land* carries out regular tests and controls during inspections of the nuclear installation, aided in most cases by authorised experts. Such inspections may be aimed at the clarification of specific issues or be performed with the objective of a general walkdown of the installation.

For example, the following areas are inspected by the nuclear licensing and supervisory authority as part of an on-site inspection:

- structures,
- confinement,
- reactor core,
- reactor coolant system,
- reactor auxiliary and supporting systems,
- ventilation systems,
- water-steam cycle,
- auxiliary and component cooling systems,
- plant auxiliary systems,
- electrical equipment,
- measuring, governing and control systems,
- reactor protection system,
- matters concerning the overall installation,
- radiation protection,
- fire (explosion) protection equipment, and
- physical protection.

For the respective areas, the on-site inspections focus on the following:

- condition/implementation as well as function and properties of the installed system on site regarding its conformity with the officially licensed or approved construction,
- maintenance or repair (including operational monitoring) of the installed system on site regarding the maintenance of its flawless condition including its conformity with the operating rules,
- operation of the installed system regarding compliance with the safety-related requirements including its conformity with the operating rules,
- confinement or retention of the activity regarding activity flow or activity inventory including conformity with the operating rules,
- documented status of the valid operating regulations regarding current updating including conformity with the rules,
- matters of radiation protection, fire protection and physical protection regarding the consideration of the present requirements including conformity with the operating rules,
- residual materials disposal regarding treatment in compliance with the specifications and regulations,
- plant documentation regarding conformity with the regulations,
- technical qualification/training of the personnel regarding maintenance of the level of training in line with the requirements including treatment in conformity with the regulations,
- quality management regarding conformity with the regulations,
- ageing management regarding conformity with the regulations, and
- safety management regarding conformity with the regulations.

Site inspections are generally aimed at reviewing the installed systems, documents and records through visual inspection on site at the installation. The relevant site inspection means/methods are therefore – depending on the kind and scope of the inspection:

- integrated visual inspection,
- specific visual inspection,
- inspection of the operating records,
- specific review of documents of the operating/quality documentation,
- recording of matters in writing,
- plausibility assessments and minor control calculations and measurements that can be carried out on site,
- comparative tests (“status quo”/”desired condition”),
- gauging/recording of process-based state variables,
- recording of the “as-built” condition, and
- interviews with the operating personnel.

The on-site inspections with the associated tests also provide a set of tools that enable the nuclear supervisory authority to assess the influencing factors of man, technology and organisation in the way they interact.

The in-service inspections carried out by the licence holder on safety-relevant components are accompanied by authorised experts of the nuclear licensing and supervisory authorities at specified intervals. Besides such inspections without special cause, other inspections also take place due to reportable events or other findings; in these cases, the nuclear licensing and supervisory authority and authorised experts on site want to form their own opinion on the findings made.

The licence holders are obligated, e.g. by licensing requirements, to submit written reports on various topic areas. These include e.g. matter of operation, safety and radiation protection including environmental monitoring as well as the stock and whereabouts of radioactive materials. The nuclear licensing and supervisory authorities, subordinate authorities or consulted experts evaluate these reports.

The current operating condition of the nuclear installations is monitored directly by the nuclear licensing and supervisory authority of the *Land* or a subordinate authority with the help of the remote monitoring system for nuclear power plants (KFÜ) (→ Article 15). With this transmission system, authority staff can monitor online the relevant operating parameters and emission data of the installation. The values that are transmitted are updated at short intervals and saved so that they are still available at a later time if needed for queries. If specified limits are exceeded, the nuclear licensing and supervisory authority is alerted automatically.

Implementation of the “Vienna Declaration on Nuclear Safety”

The SÜ required by the “Vienna Declaration on Nuclear Safety” has been carried out in Germany since the 1990s. In 2002, the obligation to perform SÜs of the nuclear installations in power operation every ten years was anchored in the AtG (§ 19a AtG). On the basis of the results of the SÜ, backfitting measures were carried out in existing installations to continually enhance the safety of the installations, as required in § 19a AtG.

By continual backfitting, the safety level of the German nuclear installations is to be maintained or improved.

Results that are seen in connection with the activities to implement the "Vienna Declaration on Nuclear Safety" can be found in this article under "Backfitting measures and improvements performed and current activities".

For nuclear installations which are finally transferred from power operation to post-operation from 2015 onwards, the licence holders have to perform a safety analysis each for the post-operational phase on the basis of the checklist for the performance of an assessment of the current safety status of the installation for the post-operational phase.

15 Radiation Protection

ARTICLE 15 RADIATION PROTECTION

Each Contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

Overview of rules and regulations

Basic regulatory requirements

The legal bases for protection against the harmful effects of ionising radiation are the Radiation Protection Act (StrlSchG) and the Radiation Protection Ordinance (StrlSchV). The StrlSchG and the StrlSchV contain provisions by which man and the environment are protected from damage due to natural and man-made ionising radiation. Requirements and limits are specified which are applied regarding the use and effects of natural and man-made radioactive substances and ionising radiation. Organisational and physical-technical protective measures and medical surveillance are prescribed. Moreover, licensing requirements are regulated for the handling of man-made radioactive substances, for their import, export and their transport.

Relevant for practices in terms of the StrlSchG are the radiation protection principles laid down therein:

- justification
- limitation of doses, and
- avoidance of unnecessary exposure and dose reduction.

Together with the principle of proportionality – a constitutional principle to be accounted for in all cases – these principles result in an obligation to optimise radiation protection in terms of the ALARA principle (As Low As Reasonably Achievable).

The main dose limits for annual effective doses, organ equivalent doses and lifetime doses laid down in radiation protection law and applicable from 31 December 2018 are listed in Table 15-1. The corresponding dose limits for the previous period are to be taken from Table 15-1 of the Report by the Government of the Federal Republic of Germany for the Seventh Review Meeting in March/April 2017.

Requirements for the protection of workers

In § 78 StrlSchG, a maximum effective dose of 20 mSv per calendar year is defined as the limit for the body dose of occupationally exposed persons. In individual cases, an effective dose of 50 mSv may be approved by the competent licensing and supervisory authority in a single year, provided that a dose over any five consecutive years does not exceed 100 mSv. Other limits are defined for organs and tissues. Stricter limits apply to persons under the age of 18 years and women of childbearing age. In exceptional situations, up to a total of 100 mSv per working life can be additionally approved by the competent licensing and supervisory authority.

In emergency situations, the limit values for occupationally exposed persons shall be applied to the emergency workers. If this cannot be ensured with reasonable effort, up to 500 mSv as a reference level for the effective dose is possible under further conditions.

Table 15-1 Limits and reference levels for body doses according to the Radiation Protection Act (StrlSchG) and the Radiation Protection Ordinance (StrlSchV) as of 31 December 2018

§	Scope of applicability	Time period	Dose [mSv]
Dose limit for occupational lifetime dose			
§ 77 StrlSchG	Effective dose	Occupational life	400
Dose limits for occupationally exposed persons over 18 years of age			
§ 78 StrlSchG	Effective dose	Calendar year	20
	Organ equivalent dose: eye lens	Calendar year	20
	Organ equivalent dose: skin (per square centimetre)	Calendar year	500
	Organ equivalent dose: hands, forearms, feet and ankles	Calendar year	500
	Organ equivalent dose: uterus (for women of childbearing age)	Month	2
	On a case-by-case basis after approval by the competent authority		
	Effective dose with authority approval	Calendar year	50
	Organ equivalent dose: eye lens with authority approval	Calendar year	50
§ 74 StrlSchV	Specially permitted **exposures** in exceptional circumstances (only voluntary adults of Category A; no pregnant women, no trainees and students, breastfeeding women only if incorporation/contamination is excluded; only after approval by the authority)		
	Effective dose	Occupational life	100
	Organ equivalent dose: eye lens	Occupational life	100
	Organ equivalent dose: skin (per square centimetre), hands, forearms, feet and ankles	Occupational life	1000
Dose limits for occupationally exposed persons under 18 years of age			
§ 78 StrlSchG	Effective dose	Calendar year	1
	Organ equivalent dose: eye lens	Calendar year	15
	Organ equivalent dose: skin (per square centimetre)	Calendar year	50
	Organ equivalent dose: hands, forearms, feet and ankles	Calendar year	50
	Effective dose: foetus (due to the professional activity of the mother)	Time of pregnancy	1
	On a case-by-case basis after approval by the competent authority		
	Effective dose: for trainees and students from 16 - 18 years with permission of the authority	Calendar year	6
	Organ equivalent dose: skin, hands, forearms, feet and ankles with authority approval	Calendar year	150
Dose limits for members of the public			
§ 80 StrlSchG	Effective dose:	Calendar year	1
	Organ equivalent dose: eye lens	Calendar year	15
	Organ equivalent dose: skin	Calendar year	50
§ 99 StrlSchV	**Dose limits for discharges to air and discharges to water**		
	Effective dose, each	Calendar year	0.3

§	Scope of applicability	Time period	Dose [mSv]
§ 104 StrlSchV	**Accident planning levels for nuclear installations**		
	Effective dose	Event	50
	Organ equivalent dose: thyroid	Event	150
	Organ equivalent dose: skin, hands, forearms, feet and ankles	Event	500
	Organ equivalent dose: eye lens, gonads, uterus, red bone marrow	Event	50
	Organ equivalent dose: bone surface	Event	300
	Organ equivalent dose: great gut, lung, stomach, bladder, breast, liver, gullet, other organs or tissues unless specified above	Event	150
Reference levels for members of the public in emergency exposure situations			
§ 93 StrlSchG	Effective dose	Year	100
Reference levels for emergency workers in emergency exposure situations			
§ 114 StrlSchG	In the event of an emergency, the limits applicable for occupationally exposed persons shall be complied with for emergency workers. Only if this is impossible with reasonable effort, the following higher reference levels can apply.		
	Emergency operations serve to protect life or health (no pregnant women or persons under 18 years of age)	Emergency event	100
	Emergency operations serve to save lives, avoid serious radiation damage or for disaster control (volunteers only)	Emergency event	250
	Emergency operations serve to save lives, avoid serious radiation damage or for disaster control in exceptional cases (volunteers only)	Emergency event	500

For the determination of body doses, the personal dose is usually measured by means of electronic dosimeters by the licence holder and with official passive dosimeters. In addition to the measurement of the dose from external exposure, the dose due to incorporation is usually determined by monitoring of the airborne activity concentration or by measuring whole-body or partial body doses.

The measuring institutions designated by the competent nuclear licensing and supervisory authorities transmit the values of official dosimetry, usually measured monthly, to the radiation protection supervisor or radiation protection officer and to the central Radiation Protection Register.

For occupationally exposed persons, a distinction is made between categories A and B. Persons with a potential occupational effective dose of more than 6 mSv/year, an organ equivalent dose higher than 45 mSv/year for the eye lens or 150 mSv/year for skin, hands, forearms, feet and ankles are classified as Category A. For these persons, occupational medical health examinations by authorised physicians are provided on an annual basis. For persons of Category B, medical examinations are only performed if specifically requested by the competent nuclear licensing and supervisory authority.

Moreover, a radiation passport is to be maintained for persons working in foreign radiologically controlled areas. Specifications for the radiation pass are laid down in § 174 StrlSchV. It must be ensured that all exposures from practices or in connection with work in the environment of naturally occurring radionuclides are taken into account for this group of persons, thus ensuring that the dose limits are complied with on the basis of the overall exposure from all areas of application.

Requirements for the protection of the public

Exposure of the public during specified normal operation

The dose limits and requirements applying to the exposure of members of the public from nuclear installations during specified normal operation are laid down in § 80 StrlSchG and §§ 99 to 102 as well as Annex 11 of the StrlSchV. As a transitional provision, the dose limits and requirements of § 47(2) in conjunction with (1) and Annex VII of the StrlSchV in the version applicable until 31 December 2018 still apply as defined in § 193 StrlSchV.

Any radioactive discharge with exhaust air and waste water is recorded nuclide-specifically according to type and activity, thus enabling the calculation of exposure in the vicinity of nuclear installations. The analytical models and parameters used to determine the exposure of the public are specified in § 100 and § 101 StrlSchV and in the general administrative provision on the determination of exposure from discharge of radioactive substances from nuclear installations or facilities. Accordingly, exposure shall be calculated for a reference person and all exposure pathways at the most unfavourable receiving points such that the exposure to be expected will not be underestimated.

Exposure of the public in the event of design basis accidents

The planned structural and technical measures for the control of design basis accidents are central issues reviewed during the licensing procedures for nuclear installations (→ Article 18 (i)). According to § 104 StrlSchV it is to be demonstrated, without prejudice to the obligations of § 8 StrlSchG, that in the vicinity of the installation in case of the most unfavourable design basis accident an effective dose of 50 mSv (accident planning level) is not exceeded by the release of radioactive substances into the environment. To this end, all exposure pathways are to be considered as a 50- or 70-year dose commitment. Further planning levels apply to specified organs and tissues. The analytical models and assumptions to be applied for verification purposes are specified in the incident calculation bases for the guideline for the assessment of the design of nuclear power plants with PWR according to § 28(3) StrlSchV and the amended calculation of radiation exposure.

Exposure of the public in the event of emergencies

Emergencies are very unlikely to occur due to the design of the nuclear installations. Organisational and technical measures were taken within the framework of on-site emergency, i.a. confirmed by the results of risk studies and probabilistic safety analysis (PSA), for the protection of the public in order to control design extension conditions or at least to mitigate their consequences inside and outside the installation (→ Article 18). This is to prevent radiological situations which require drastic actions, such as evacuations or long-term resettlements. Notwithstanding this on-site emergency response, additional measures can be taken, if required, for the protection of the public within the framework of off-site emergency planning (→ Article 16) if there are significant releases or the risk of such releases.

Implementation of the ALARA principle

The protection of the persons working in nuclear installations has already been considered during the design of the nuclear installations by implementing the provisions of the radiation protection law and subordinate rules and regulations (e.g. the guideline for radiation protection of personnel during the execution of maintenance work in nuclear power plants with light water reactors, Part 1 and safety standard KTA 1301.1 "Radiation Protection Considerations for Plant Personnel in the Design and Operation of Nuclear Power Plants; Part 1: Design"). The design-related aspects are also taken into consideration in case of significant modifications of nuclear installations. In addition, organisational and technical measures are specified for the reduction of exposure of personnel during operation (in particular the guideline concerning the radiation protection of personnel during maintenance, modification, waste management and dismantling work in nuclear installations and facilities, Part 2 and safety standard KTA 1301.2 “Radiation Protection Considerations for Plant Personnel in the Design and Operation of Nuclear Power Plants; Part 2: Operation”).

The planning processes regarding the required radiation protection measures to be taken when carrying out activities in nuclear installations are dependent on the individual and collective doses to be expected as well as on the radiologically relevant boundary conditions. Radiation protection has principally to be included in the planning at an early stage. Depending on the individual case, the planning is also subject of reviews by the nuclear supervisory authority.

In general, the basic ideas of the ALARA principle are included in the licence holders’ radiation protection measures. These are i.a. geared to

- involving the management in radiation protection responsibilities and the support of the implementation,
- the decision-making strategy to solve the issue of meeting complex radiation protection requirements,
- the proportionality of the radiation protection measures, and
- the evaluation of experience and experience feedback.

The requirements together with the increased radiation protection awareness among the personnel and the involvement of the nuclear licensing and supervisory authorities in the review of the planning of radiation protection measures and their implementation provide a good basis for the implementation of the ALARA concept with the aim to reduce exposures and optimise radiation protection measures in the installations.

An example of the improvement of the radiologically relevant boundary conditions represents the primary circuit system decontamination performed in some nuclear installations, in particular for nuclear installations in the post-operational phase. This measure allows to permanently reduce the exposure of personnel during the planned activities.

Emission and immission monitoring

Maximum permissible activity amounts and concentrations for the discharge of radioactive substances are defined by the nuclear licensing and supervisory authorities within the framework of the procedure for granting an operating licence.

These are calculated such that, under consideration of the site-specific dispersion conditions and exposure pathways, the potential exposure for members of the public resulting from the discharge does not exceed the limits of § 99 StrlSchV (→ Table 15-1). Together with the contribution by direct radiation, the limits of § 80 StrlSchG (→ Table 15-1) shall not be exceeded.

Discharges of radioactive substances are to be kept as low as possible, taking into account the state of the art in science and technology and all circumstances of the individual case, even where the limits are below those defined in the operating licence. Thus, for example, high demands are placed on the quality of the fuel assemblies, the composition of the materials, and the purity of the water used in the primary system for activity limitation and for preventing the contamination of components and systems. In addition, the nuclear installations are equipped with devices for the retention of radioactive substances.

Emission monitoring

The basis for monitoring and specification of emissions according to type and activity is provided by § 99 and 103 StrlSchV. The programmes for emission monitoring during specified normal operation and in case of design basis accidents comply with the guideline concerning emission and immission monitoring of nuclear installations (REI) and safety standards KTA 1503.1 “Monitoring the Discharge of Radioactive Gases and Airborne Radioactive Particulates; Part 1: Monitoring the Discharge of Radioactive Matter with the Stack Exhaust Air During Specified Normal Operation", KTA 1503.2 "Part 2: Monitoring the Discharge of Radioactive Matter with the Vent Stack Exhaust Air During Design-Basis Accidents", KTA 1503.3 "Part 3: Monitoring the Non-stack Discharge of Radioactive Matter" and KTA 1504 "Monitoring and Assessing the Discharge of Radioactive Substances with Water". The licence holders of the nuclear installations carry out these monitoring measures and submit the results to the competent nuclear licensing and supervisory authorities.

The sampling and measurement methods are oriented towards the two tasks of monitoring by continuous measurement on the one hand, and sampling for specifying the discharge of radioactive substances via the paths exhaust air and waste water according to type and amount on the other hand.

The specification of the discharge with exhaust air comprises the following nuclides and nuclide groups: radioactive noble gases, radioactive aerosols, radioactive gaseous iodine, tritium, radioactive strontium, alpha emitters and carbon-14. For the water path, quantities are specified for gamma emitting nuclides, radioactive strontium, alpha emitters, tritium, iron-55 and nickel-63. Reports on the discharges specified in terms of type and activity are submitted to the nuclear licensing and supervisory authority on a quarterly and annual basis.

Releases that may occur as a result of accidents are determined using instruments with extended measurement ranges. In addition to the measuring instruments of the licence holders, there are also instruments of the nuclear licensing and supervisory authorities whose data are transmitted online via the remote monitoring system for nuclear power plants (KFÜ).

Direct radiation from the nuclear installation is monitored by dose measurements at the fence of the site.

To assess the effects of discharged radioactive substances, the licence holder of the nuclear installation records the site-specific meteorological and hydrological parameters with relevance for the dispersion and deposition of radioactive substances. The requirements for meteorological instrumentation are included in safety standard KTA 1508 "Instrumentation for Determining the Dispersion of Radioactive Substances in the Atmosphere".

Immission monitoring

The licence holders of the nuclear installations have implemented a programme for immission monitoring in the vicinity of the installations as ordered by the nuclear licensing and supervisory authority. In addition, measurements are performed by independent measuring institutions on behalf of the licensing and supervisory authority.

Immission monitoring supplements emission monitoring. It allows additional control of the discharges as well as control of compliance with the dose limits in the vicinity of the installation. The REI specifies programmes for immission monitoring prior to commissioning, during specified normal operation, during design basis accidents or emergencies as well as in the phase of decommissioning and safe enclosure for the licence holder and the independent measuring institution. Site-specific circumstances and conditions are considered additionally.

The still uninfluenced environmental radioactivity and exposure was recorded by measurements prior to commissioning. Monitoring measures during operation serve, among other things, to monitor long-term changes that may occur due to the discharge of radioactive substances. Incident and accident measurement programmes provide the basis for sampling, measurement and evaluation methods in the event of a design basis accident or emergency. The sampling and measurement methods ensure that relevant dose contributions for the public by external exposure, inhalation and ingestion can be identified during specified normal operation and can be determined in the event of a design basis accident or emergency. The results of immission monitoring are submitted to the nuclear licensing and supervisory authority and are centrally recorded, evaluated and published by the Federal Office for Radiation Protection (BfS).

Even when using the most sensitive analysis methods, no immission in the environment will be detected that result from discharges with exhaust air. The analysis of the ground-level air, the precipitation, the soil, the vegetation and the foodstuffs of plant and animal origin shows that the content of long-lived radioactive substances, such as caesium-137 and strontium-90, does not differ from the values measured at other locations in Germany. Short-lived nuclides that might originate from the operational discharges with exhaust air also are not detected.

The discharge of radioactive substances from nuclear installations is usually detectable in surface water samples in the vicinity of the respective sites. The tritium content of flowing waters is generally significantly increased by discharges of radioactive waste water from nuclear installations. The values are mostly below 100 Bq/l. In samples directly taken at discharge structures, increased H-3 concentrations of some 100 to 1,000 Bq/l are measured. As a result of mixing along the flow section, however, the H-3 concentrations quickly decrease again. The activity concentrations of other relevant fission and activation products usually fall below the detection limit of the REI of 0.05 Bq/l. In particular, Sr-90 and Cs-137 are not to be explicitly identified due to the existing contamination from other sources (nuclear fallout and reactor accident in Chernobyl). This also applies to I-131, which is attributable to nuclear medicine applications. Transuranic elements are generally not detected.

In sediment and suspended matter samples, in some cases I-131, Cs-137 and Am-241 with specific activities are detected mostly below 50 Bq/kg dry weight. However, particularly in lakes (Starnberger See, Schollener See, Schaalsee, Wittensee), three-digit values up to about 400 Bq/kg dry weight also occur for Cs-137 as a result of the reactor accident in Chernobyl. Otherwise, the average specific activities of the installation-typical radionuclides are below the detection limit of REI of 5 Bq/kg dry weight.

The increase in the content of fission and activation products in surface water caused by discharges of radioactive waste water from nuclear installations is negligible from a radiological point of view. In fish, aquatic plants, groundwater and drinking water, radiologically relevant amounts of radioactive substances are not detectable either which are attributable to the operation of a nuclear installation.

Monitoring of environmental radioactivity/Integrated Measurement and Information System

In addition to the site-specific monitoring of the vicinities of the nuclear installations, the general radioactivity in the environment is recorded by extensive measurements in the entire territory of the Federal Republic of Germany on the basis of the StrlSchG by means of the Integrated Measurement and Information System for the Monitoring of Environmental Radiation (IMIS). Monitoring comprises all relevant environmental areas from the atmosphere and the surface waters up to sampling of foodstuffs and drinking water. Core piece is a network which, at present, comprises about 1,800 measurement stations for measuring the local gamma dose rate. All data measured are continuously transmitted to the Central Federal Agency (ZdB) for the surveillance of radioactivity operated by the BfS and from there on to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Even slight changes in the level of environmental radioactivity can be detected quickly and reliably by the measurements, making it possible to give early warnings to the public, if so required. In the event of increased values in the territory of the Federal Republic of Germany, IMIS will be switched from routine to intense operation on the initiative of the BMU, which essentially means that measurements and samples will be taken more frequently.

The results from these measurements are also used within the framework of international information exchange (→ Article 16 (2)).

The IMIS measurement data are made available to the public on the Internet at https://www.imis.bfs.de/geoportal/. Activity concentrations in the air are presented with daily updates and local gamma dose rates with hourly updates in map form for the federal territory. Figure 15-1 shows an example of data for the local dose rate from the year 2019.

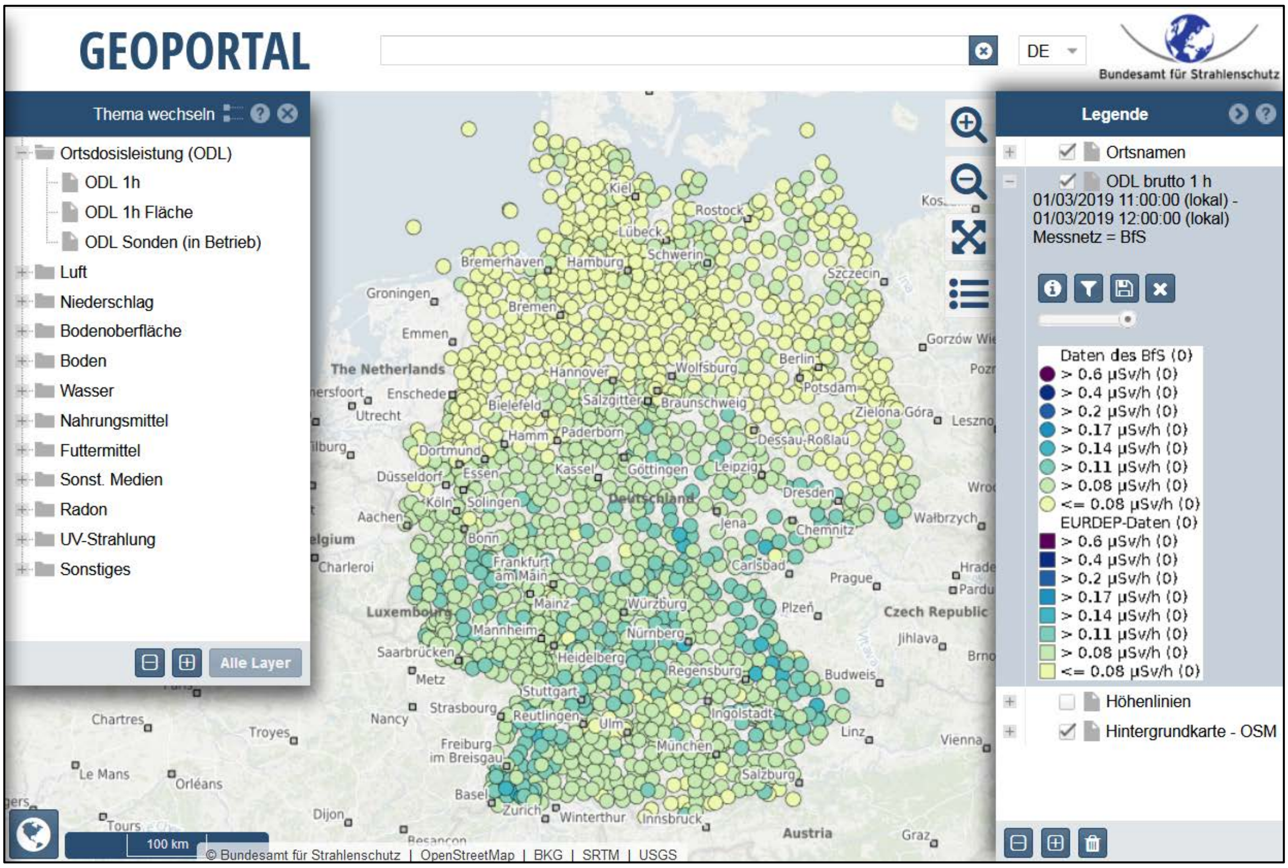


Figure 15-1 Example of the determination of environmental radioactivity by gamma dose rate measurements

Results of the implementation of radiation protection measures by the licence holder

Exposure of the personnel

Figure 15-2 shows the average collective doses per year and nuclear installation. Here, to some extent, the construction lines show different behaviours. The exposures at PWRs of construction line 4 (Konvoi plants) have remained at a consistently low level since commissioning. An important contribution to this was i.a. consistently not using materials containing cobalt in almost all components of the primary system. Further structural improvements, such as enlarged space and additional structural shieldings compared with previous construction lines, also contributed to reducing exposure. The increases in the annual collective doses in 2010 and 2015 are due to extensive revision activities in two (2010) and one (2015) of the four PWRs of construction line 4. Construction line 3 shows a long-term reduction in collective doses. This is mainly due to the improvement of radiation protection and the small scope of backfitting measures compared to previous years. The differences from year to year are due to different scope of revision activities during maintenance and refuelling outage. In 2015, one PWR of construction line 3 was permanently shut down, which is why the revision rhythm of the two remaining PWRs in power operation no longer leads to such pronounced differences in the annual collective dose of construction line 3 as in previous years.

In the case of boiling water reactors (BWRs) (construction line 72), slightly higher revision doses within the scope of extensive revision activities led to an increase in collective doses in the period from 2003 to 2008. With decreasing scopes of revisions, the average annual collective dose stabilises in the following years at a lower level than in 2008. There is no discernible revision rhythm for this construction line, as the maintenance and refuelling outages of the two SWRs are usually carried out in a complementary manner.

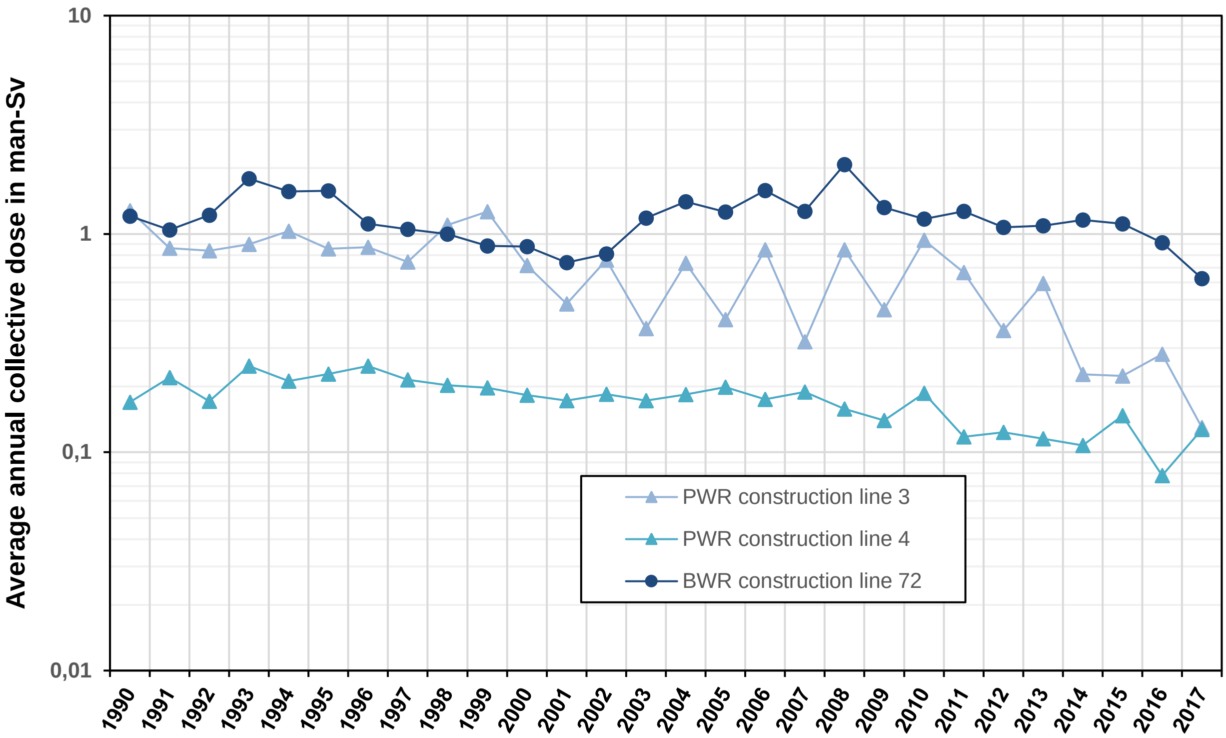


Figure 15-2 Average annual collective doses of occupationally exposed persons at nuclear installations in operation per year and installation according to construction line

Discharge of radioactive substances during operation of the installations

Results of emission monitoring

Except for tritium, the annual discharges are only in the order of a few percent of the specified limits. The data on discharges of radioactive substances with exhaust air and waste water are published by the Federal Government in its annual report "Environmental Radioactivity and Radiation Exposure" submitted to the *Bundestag* (the German Federal Parliament), and in an additional more detailed annual report with the same name issued by the BMU. Discharges from German nuclear installations are shown in Figures 15-3 and 15-4.

Exposure of the public during specified normal operation

The results of the calculation of radiation exposure of the public show (→ Figures 15-5 to 15-7) that the discharges with exhaust air only lead to doses in the range of a few µSv per year due to the measures implemented at the nuclear installations in operation, the filtering devices installed and fuel assembly defects to only a small extent. The relevant limit of 0.3 mSv for the effective dose is only reached to a fractional amount for the reference person (a person behaving very unfavourably with regard to exposure), who is transitionally still considered due to § 193 StrlSchV. For waste water, the resulting exposures are even lower, with values generally less than 1 µSv. These calculations were carried out according to the general administrative provision on the determination of exposure from discharge of radioactive substances from installations or facilities.

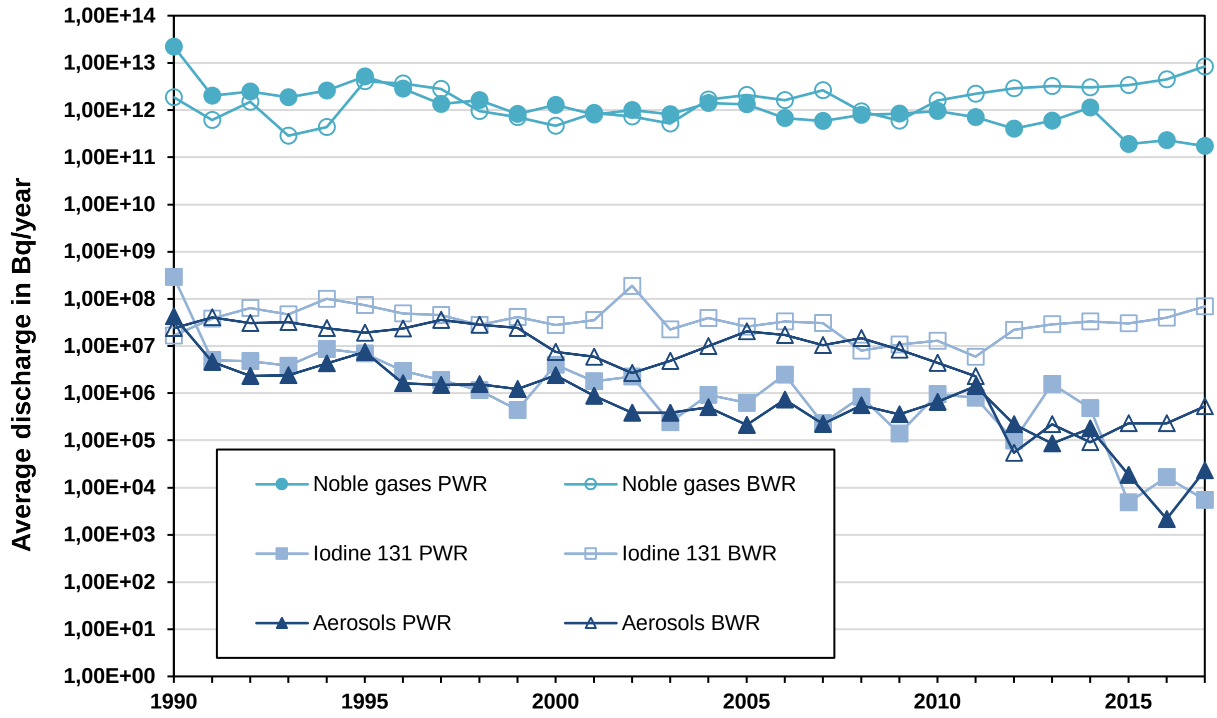


Figure 15-3 Annual average discharge of radioactive substances with exhaust air from PWRs and BWRs in operation

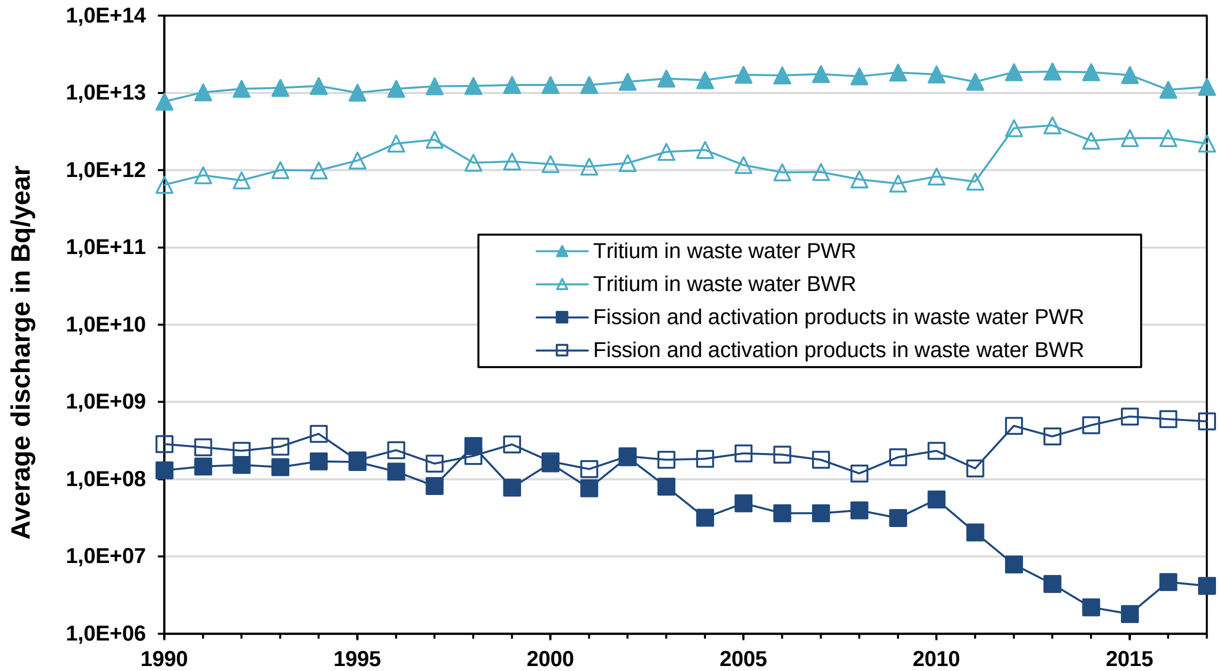


Figure 15-4 Annual average discharge of radioactive substances with waste water from PWRs and BWRs in operation

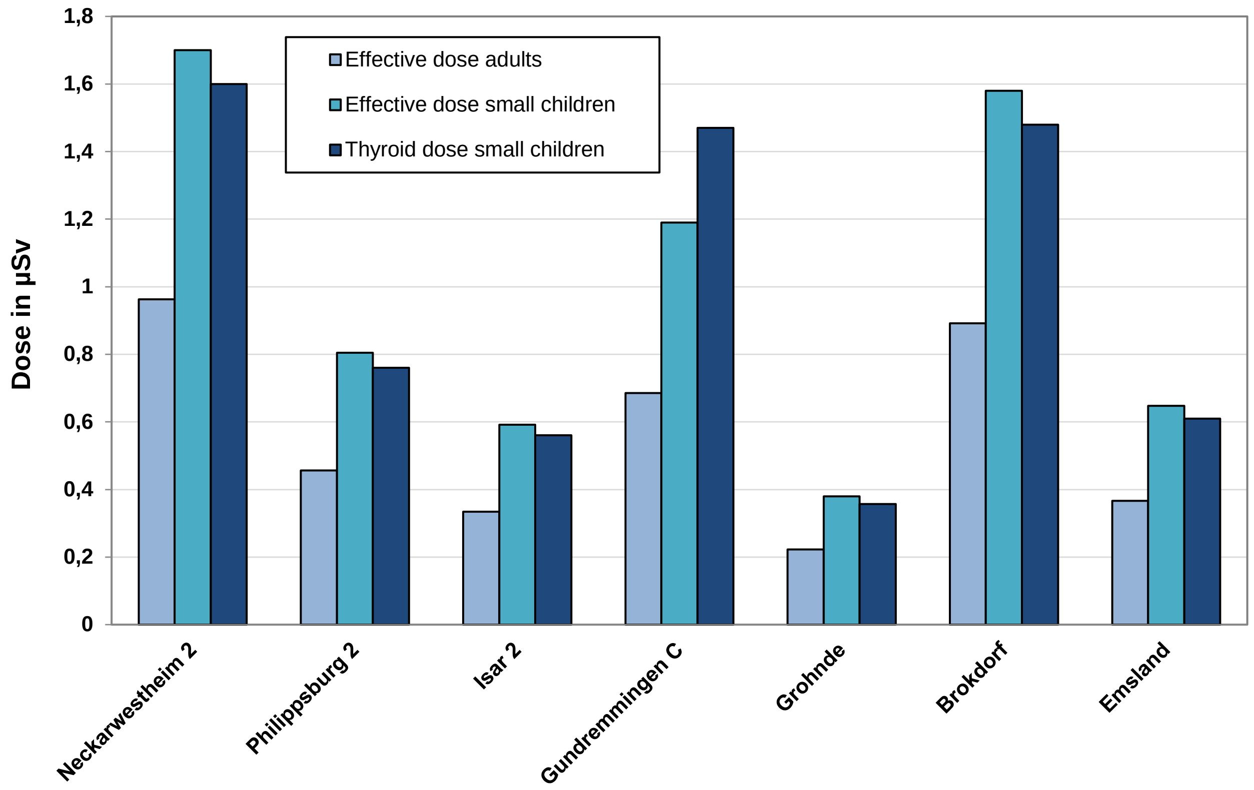
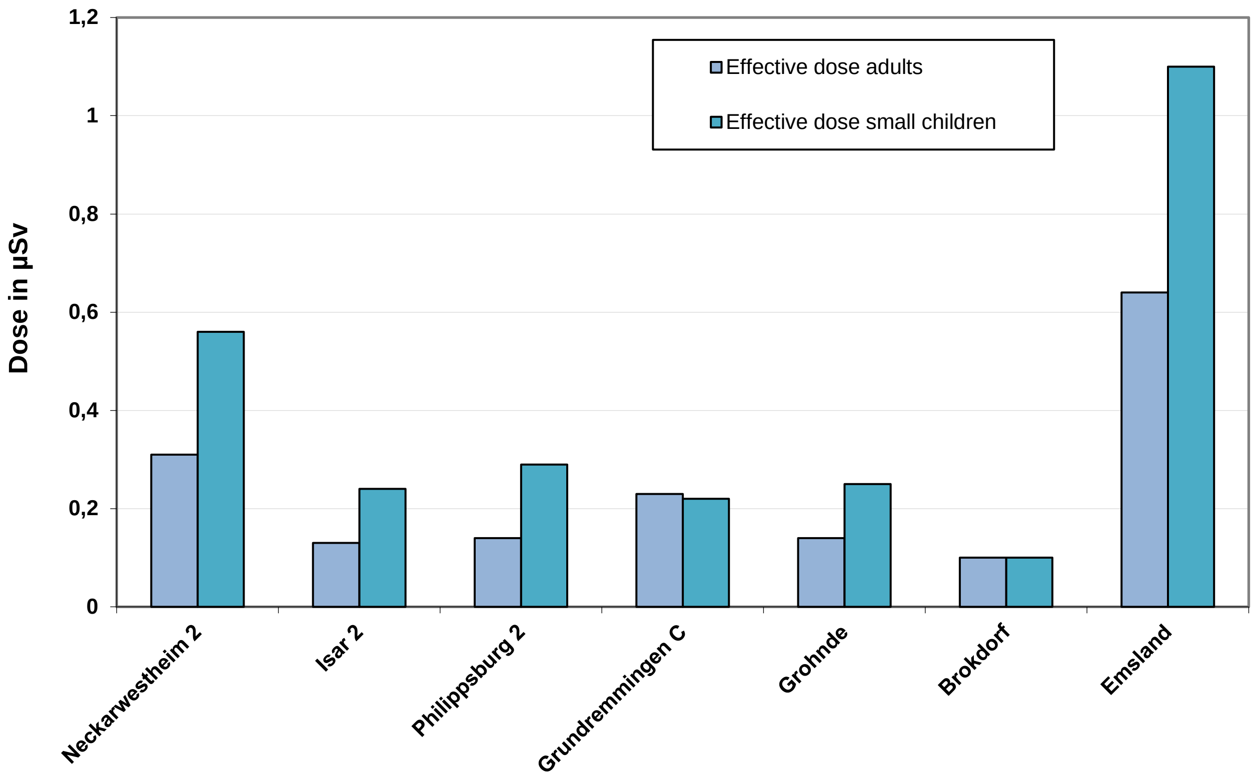


Figure 15-5 **Radiation exposure in 2017 in the vicinity of the nuclear installations in operation due to discharges with exhaust air**



Note: Values < 0.1 µSv are displayed as 0.1 µSv.

Figure 15-6 **Exposure in 2017 in the vicinity of the nuclear installations in operation due to discharges with waste water**

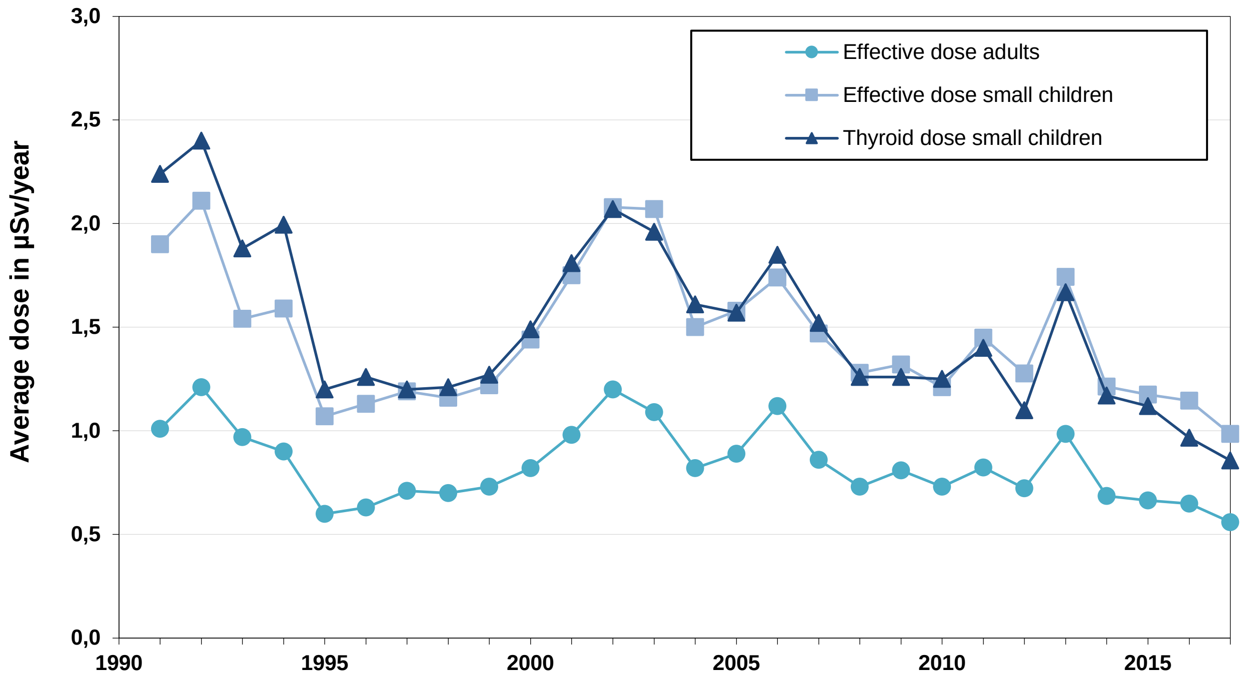


Figure 15-7 Average exposure in the vicinity of the nuclear installations in operation due to discharges with exhaust air

Regulatory review and monitoring

Emission monitoring

Primarily, emission monitoring is the responsibility of the licence holder who causes the emissions (self-monitoring). The licence holder has to specify the discharges of radioactive substances according to type and activity and furnish proof of compliance with the maximum permissible (licensed) discharges to the licensing and supervisory authority. The licence holder supplements the proof of compliance with the dose limits by means of an additional measurement programme for the monitoring of the vicinity of the installation or facility.

Control of performance of emission monitoring and of specification of the results of emission monitoring according to type and activity by the licence holder (self-monitoring) is assigned to the BfS pursuant to § 103(4) StrlSchV.

In accordance with the guideline on the verification of the licence holder's monitoring of radioactive effluents from nuclear power plants, measurements are performed on aerosol filter samples, iodine filter samples, tritium samples and carbon-14 samples for the control of emission monitoring of exhaust air, and comparative measurements are performed to determine the emission of radioactive noble gases. For controlling emission monitoring of waste water, samples are analysed for gamma-emitting nuclides, tritium, strontium and alpha emitters. The results of the control measurements are submitted to the nuclear licensing and supervisory authorities. If the results of the measurements carried out by the licence holder correspond with those carried out by the BfS within the measurement-related error tolerance, it can be assumed that the radioactive emissions are recorded correctly, and type and activity are specified correctly.

In addition, the licence holders are required to participate in round robin tests.

Immission monitoring

The immission measurements carried out by the nuclear licensing and supervisory authorities of the *Länder* in the vicinity of nuclear installations and facilities supplement the emission monitoring measures of the licence holder and the BfS. Furthermore, they give information about potential long-term changes in the environmental radioactivity due to operational discharges.

Within the scope of the measuring programmes carried out by the nuclear licensing and supervisory authorities of the *Länder* in the vicinities of the nuclear installations and facilities, the respective local doses and local dose rates are determined at the selected locations or sites, and samples are taken of different environmental media (air, water, soil) and agricultural products (feed and foodstuff) for subsequent laboratory evaluation.

Besides direct supervisory radiation protection measures in the individual nuclear installations, the respective nuclear licensing and supervisory authorities also monitor the emission and immission of radioactive substances with exhaust air and waste water. For immission monitoring, the competent nuclear licensing and supervisory authorities of the *Länder* operate measuring systems and facilities to be able to detect increased discharges of radioactive substances, e.g. in case of an incident, at an early stage.

Within the scope of his responsibility for emission monitoring, the licence holder regularly reports to the competent nuclear licensing and supervisory authority on the discharges of radioactive substances which are reviewed for completeness, plausibility and consistency. In doing so, data of immission monitoring carried out by the *Land* and the BfS are also taken into account. Any discrepancies will be examined within the scope of supervision. Where required, additional measurements (special measurements) are initiated for clarification. In addition, correct performance and specification of the results of emission monitoring according to type and activity is verified by control measurements.

Remote monitoring of nuclear power plants

In addition to the self-monitoring of the licence holder, the competent nuclear licensing and supervisory authorities of the *Länder* operate their own systems for continuous acquisition of measurement data (KFÜ).

Main functions of the KFÜ are the continuous emission monitoring, which is partly designed redundantly to the self-monitoring of the licence holders, and immission monitoring in the vicinity of the nuclear installations. Furthermore, meteorological data are continuously transmitted to the nuclear licensing and supervisory authority. Various operating parameters provide information on the operational status of the nuclear installations.

The use of the data acquired within the KFÜ mainly cover the regulatory supervision of the operational processes and automatically initiated alerting of the nuclear licensing and supervisory authority in the case of excess of permitted values. Thus, the results also serve the purposes of disaster control.

Progress and changes

In the area of statutory regulations, the StrlSchG was promulgated in 2017. Individual parts of this new Act, in particular on emergency preparedness and response and monitoring environmental radioactivity, as well as a supplementary ordinance on the competence for IMIS, already entered into force in 2017. The remaining provisions of the StrlSchG then entered into force together with the new StrlSchV on 31 December 2018.

16 Emergency preparedness

ARTICLE 16 EMERGENCY PREPAREDNESS

1. Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body
2. Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.
3. Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.

Structure of the legal and administrative framework for emergency preparedness

The licence holder is responsible for on-site emergency preparedness. The legislative requirements for this are mainly contained in the Atomic Energy Act (AtG), the Radiation Protection Act (StrlSchG) and the ordinances based thereon.

In accordance with Directive 2013/59/Euratom, the framework for off-site emergency preparedness and response is referred to in the StrlSchG as the emergency management system of the Federation and the *Länder*. In addition to the StrlSchG and its ordinances, the emergency management system is based on the general legal provisions of the Federation and the *Länder*, which serve to avert dangers to human health, the environment or public safety, as well as corresponding directly applicable legal acts of the European Union (EU) and the European Atomic Energy Community (Euratom).

Both in the area of on-site and off-site emergency preparedness, the legislative requirements (→ Article 7) are specified and supplemented in a large number of substatutory regulatory documents which contain further elements of the emergency plans within the meaning of Article 16 (1).

Emergency preparedness includes on-site and off-site emergency planning as well as the provision of technical and organisational measures to cope with an imminent or already occurred emergency exposure situation (→ Figure 16-1).

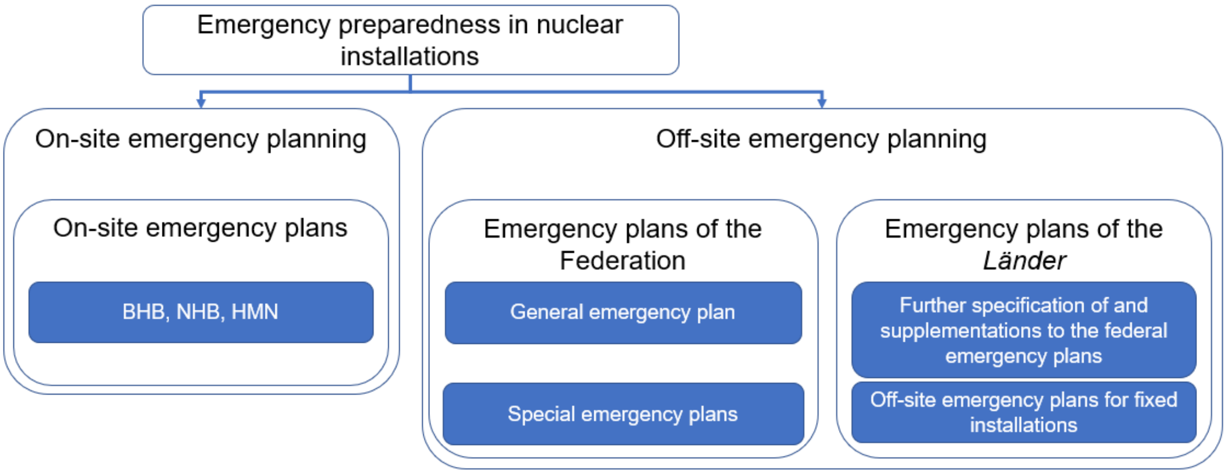


Figure 16-1 Structure of emergency preparedness in nuclear installations

On-site emergency planning is implemented by internal regulations for technical and organisational measures of the licence holder which can be taken in nuclear installations to control an event or to mitigate its consequences.

Off-site emergency planning refers to all legal, administrative, technical and organisational measures of short-, medium- and long-term emergency management which are taken by the Federation and the *Länder* in a legislative and executive manner so that, in accordance with the principles of emergency preparedness and response laid down in the StrlSchG, in the case of an emergency,

1. the reference levels laid down in the StrlSchG for the protection of the population and the emergency workers will, as far as possible, not be reached, and
2. the exposure of the population and the emergency workers as well as the contamination of the environment in the event of emergencies can be kept as low as possible even below the reference levels by way of appropriate measures, taking into account the state of the art in science and all circumstances of the respective emergency.

16 (1) Emergency preparedness, emergency plans

Legal and regulatory requirements

Legal and regulatory requirements for on-site emergency plans

The emergency manual (NHB) represents the on-site emergency plan of the licence holder. Requirements regarding the contents of the NHB are prescribed by law in §§ 7c and 7d AtG and specified in the "Safety Requirements for Nuclear Power Plants" and safety standard KTA 1203 "Requirements for the Emergency Manual" (→ Article 7 (2i)).

Legal and regulatory requirements for off-site emergency plans

The StrlSchG contains a number of legislative requirements for the preparation of new, coordinated emergency plans of the Federation and the *Länder* not finalised yet as well as for emergency plans for fixed installations and facilities with special hazard potential.

The competent German governmental and administrative bodies are bound by EU and Euratom legal acts as well as by provisions of the Federation and the *Länder* when drawing up off-site emergency plans. Among the legal acts are Council Regulation (Euratom) 2016/52 of 15 January 2016 laying down maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency, and repealing Regulation (Euratom) No 3954/87 and Commission Regulations (Euratom) No 944/89 and (Euratom) No 770/90 authorising the European Commission, in the event of a nuclear accident or other radiological emergency, to establish uniform limits for radioactive contamination in the internal European market, above which contaminated food and feed must not be placed on the market. Further regulations concerning emergency response can be found in the Emergency Dose Level Ordinance (NDWV) with fixed dose levels for the measures "request to stay in buildings", "request to take iodine tablets" and "evacuation" as well as the Radiation Protection Ordinance (StrlSchV) with specifications regarding the protection of emergency workers.

Part of the planning is a definition of the decision-making process for measures to protect the population and the emergency workers as well as a description of the responsibilities in the federal system.

In the general emergency plan of the Federation, certain reference scenarios are to be defined on the basis of assessments of possible emergencies in Germany and abroad, which serve the Federation and the *Länder* as a common basis for their planning of appropriate response to these and other possible emergencies. For these reference scenarios, the general emergency plan of the Federation shall present i.a. optimised strategies for the protection of the population and the emergency workers, which shall in particular comprise the following:

- dose levels used as a radiological criterion for the adequacy of certain protective measures,
- criteria for triggering the alert and for taking certain protective measures (triggering criteria), in particular measurands or indicators of the conditions at the location of the radiation source, and
- limit or guideline values relating to specific, directly measurable consequences of the emergency, e.g. dose rates, contamination levels or activity concentrations.

Furthermore, the general emergency plan has to include requirements for reviewing and adapting the protection strategy and measures to the developing radiological situation and changes in the other relevant circumstances of the respective emergency, also including criteria and procedures for the lifting of measures. This will complete the only challenge still open at the Seventh Review Meeting from the Sixth Review Meeting (developing criteria and standards to lift measures after an event with major release and allowing the population to return to affected areas) during the development of the general emergency plan.

The general emergency plan of the Federation is to be specified by special federal emergency plans for specific administrative and economic sectors (e.g. agriculture, food and feed, contaminated products, objects and waste, goods transport). The federal plans are underpinned by general and special emergency plans of the *Länder*.

Until the federal emergency plans have been adopted, the corresponding currently applicable stipulations and descriptions in general administrative provisions, SSK recommendations and other planning documents listed in Annex 4 StrlSchG shall provisionally be regarded as federal emergency plans.

Legal and regulatory requirements for monitoring environmental radioactivity and assessing the radiological situation

The StrlSchG also specifies the tasks and powers of the nuclear and radiation protection licensing and supervisory authorities of the Federation and the *Länder* with regard to the monitoring of environmental radioactivity and the assessment of the radiological situation in the event of a radiological emergency. In addition, it regulates the tasks of other authorities of the Federation and the *Länder* which are also responsible for the defence against hazards to human health, the environment or public safety in the case of other events. For this purpose, it contains regulations on the following:

- measurement tasks of the Federation and the *Länder* for monitoring environmental radioactivity,
- operation of an integrated measuring and information system for the monitoring environmental radioactivity (IMIS) under the responsibility of the Central Federal Agency (ZdB) at the Federal Office for Radiation Protection (BfS),
- authorisation to lay down binding limits for emergency-related contamination levels or dose rates by statutory ordinances, covering all areas from drinking water, food, feed, commodities, pharmaceuticals and other products as well as cross-border traffic and contaminated areas to the laying down of emergency-related dose and contamination levels for individuals of the population,
- authorisations to regulate the management of waste that is radioactively contaminated or may be contaminated as a result of an emergency by statutory ordinance,
- official information and specific behavioural recommendations for the population,

- content of a radiological situation report (RLB), a report prepared regularly during an emergency with all relevant information on the radiological situation and on the tasks involved in determining and evaluating the radiological situation, and
- establishment of the Federal Radiological Situation Centre (RLZ).

Tasks and responsibilities

On-site emergency planning is the responsibility of the licence holder of a nuclear installation. Off-site emergency planning falls within the competence of the respective authorities of the *Länder* and the Federation. Authorities of the Federation and the *Länder* that perform hazard prevention tasks in everyday business or other crisis situations in a specific area of life or economic sector (e.g. in disaster control, medical care, food and feed safety) generally retain this responsibility in the event of radiological emergencies. The relevant bodies, parties and facilities involved in emergency management of the Federation and the *Länder* are shown in Figure 16-2. The arrows indicate the interfaces and information flow directions between them.

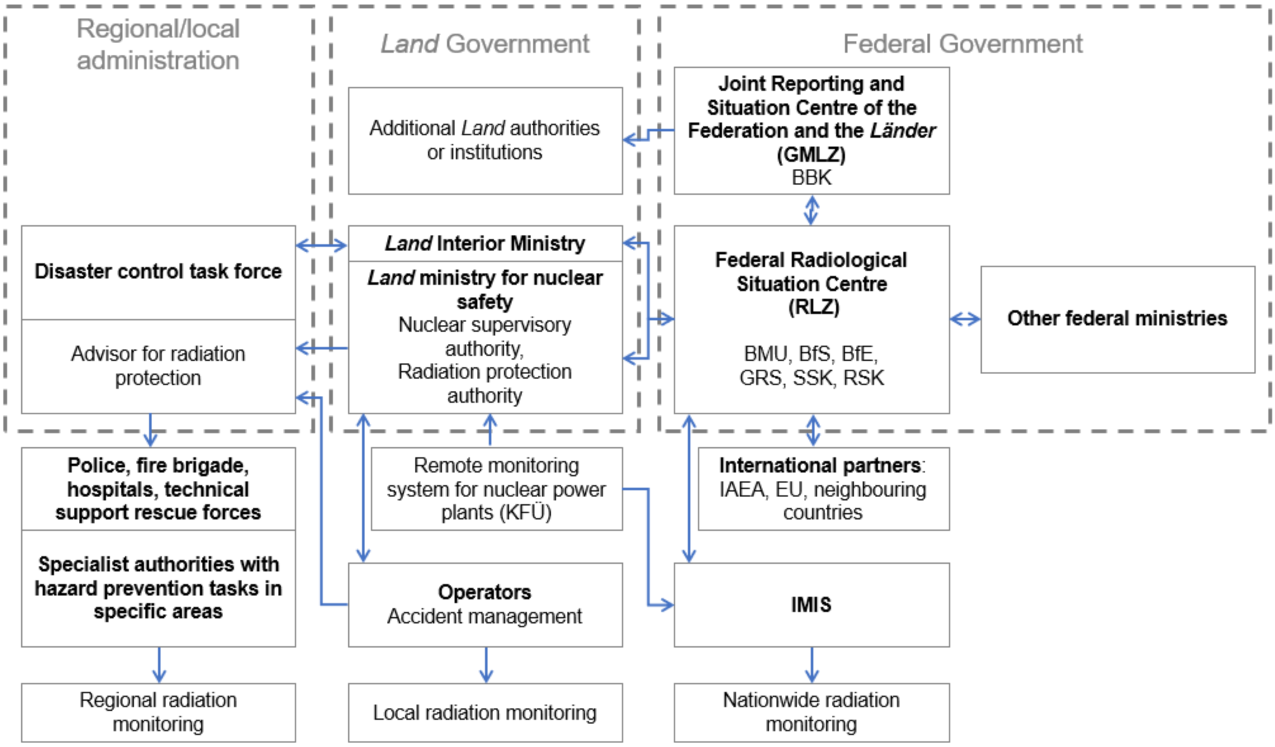


Figure 16-2 Emergency preparedness organisation

Tasks and responsibilities of the licence holder of a nuclear installation

Within the framework of on-site emergency planning, the licence holder is responsible for ensuring that, in the event of incidents and accidents, the risks to man and the environment are kept as low as possible.

The measures of the licence holder are divided into preventive and mitigative measures. The overriding objectives of the preventive measures are the achievement and maintenance of a plant condition that cannot lead to any dangerous effects, as well as the prevention of accidents with severe fuel damage. The mitigative measures serve to limit the damage in the event of imminent or occurred core damage. The Reactor Safety Commission (RSK) and the Commission on Radiological Protection (SSK) have jointly formulated general recommendations for the planning of emergency protection measures of the licence holder. These were last revised in 2014 and now include i.a. lessons learned from the nuclear accident in Fukushima. The emergency plans of the licence holders ensure that these measures can be implemented without delay.

The licence holder immediately informs the competent authorities in the event of an emergency as soon as the specified prerequisites for an alarm are fulfilled. The licence holder is obliged to provide the authorities with the information necessary for averting danger in time and appropriate to the situation and to advise and support the authorities in determining the situation and in deciding on protective measures for the population.

Tasks and responsibilities of the authorities of the *Länder*

The short-term emergency management measures include measures to prevent hazards by disaster control. This is the task of the *Länder* which have enacted special disaster control laws for this purpose. In the *Länder*, disaster control falls within the competence of the authorities of the interior and is delegated to regional or also to the local level, depending on the *Land*. The disaster control management has the decision-making authority over the ordering of hazard prevention measures and, in areas for which a disaster situation has been declared, also manages the deployment of all other *Land* authorities and aid organisations involved in combating the disaster. *Land* authorities that perform hazard prevention tasks in everyday business or other crisis situations in a specific area of life or economic sector also perform these tasks in the case of nuclear accidents and radiological emergencies in areas for which no disaster situation was declared or the disaster alarm was lifted at a late stage of the emergency.

In the event of regional emergencies, the *Land* is responsible for drawing up the RLB, unless other agreements have been made with the Federation. In the *Länder* with nuclear installations, the licensing and supervisory authorities operate the remote monitoring system for nuclear power plants (KFÜ) for local monitoring of the radiological situation. Since in some *Länder* nuclear installations were shut down or are being dismantled and thus the focus of monitoring changed, this system was renamed at some locations to remote radiological monitoring of nuclear installations or remote reactor monitoring of nuclear installations (both abbreviated as RFÜ).

Tasks and responsibilities of the authorities of the Federation

In the event of transregional emergencies, which by definition include all emergencies at nuclear installations, the RLZ is always responsible for drawing up the federal RLB, which is binding for all authorities. The RLZ is a network consisting of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), BfS, the Federal Office for the Safety of Nuclear Waste Management (BfE), Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH and supporting federal authorities and is in close contact with the *Länder*, other federal ministries and, in particular, with closely neighbouring countries. The RLZ is not only responsible for drawing up the RLB but also for coordinating the measures and measurements. In principle, the law stipulates that the *Länder* may conclude an agreement with the RLZ to draw up the RLB also for regional emergencies, i.e. such emergencies that typically affect only one *Land*.

The BMU is also responsible for the fulfilment of international information and reporting obligations, e.g. for the implementation of the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, the International Health Regulations[19] as well as for the exchange of information in accordance with bilateral agreements for emergencies and fulfils these obligations with the RLZ. In parallel to the radiological situation assessment, the RLZ determines the support needed, e.g. to be able to specifically request nationally required assistance via the Response and Assistance Network (RANET) or to respond to requests in the event of emergencies abroad.

[19] Act on the Implementation of the International Health Regulations (IGV-DG), Federal Law Gazette I 2013 p. 566

The Federation monitors and assesses the radiological situation with the ZdB at the BfS. For this purpose, it uses the data from IMIS to monitor the radiological situation in Germany both in routine operation and in the event of incidents or emergencies with a higher measurement and sampling frequency ($\rightarrow$ Article 15). In an emergency, the ZdB is integrated in the RLZ.

The German Joint Reporting and Situation Centre (GMLZ) is the national contact point responsible for alerting the RLZ in the event of radiological emergencies abroad during the alerting process.

Alerts and emergency plans

Various alarm routes are planned in Germany for incidents and emergencies at nuclear installations. According to the on-site emergency plans of the licence holder, the off-site emergency plans for fixed installations or facilities with special hazard potential and the alert criteria and other stipulations to be observed as a provisional emergency plan of the Federation, the licence holder or certain authorities are obliged to inform the nuclear supervisory authority, the local authority responsible for public safety, the disaster control authorities and the RLZ immediately if a reportable event fulfils certain specified alert criteria. These authorities may alert other authorities, organisations, neighbouring and affected third countries, the EU and international organisations specified in the general and special emergency plans of the Federation and the *Länder*.

Accordingly, the first alert of the competent German authorities is issued

- in the case of events in German nuclear installations, generally by the licence holder of a nuclear installation,
- in the case of events occurring abroad, generally by the competent foreign authorities, the International Atomic Energy Agency (IAEA) or other international organisations on the basis of the international or bilateral regulations and agreements concluded for this purpose, or
- when certain parameters of the automated plant-related environmental monitoring are exceeded, by the nuclear licensing and supervisory authorities, or
- when certain parameters of the IMIS monitoring are exceeded, by the ZdB for the monitoring of environmental radioactivity.

On-site alerts and emergency plans

The alarm regulation of the licence holder of a nuclear installation contain the regulations for alerts in the event of incidents and emergencies. It is part of the operating manual (BHB) and belongs to the safety specifications. RSK and SSK have jointly recommended criteria for the alert of emergency response authorities by the operators of nuclear plants. These make a distinction between the two alert stages “early warning” and “emergency alert”:

- **Early warning** is triggered if an event at the nuclear installation has not yet had any impact on the environment, or only a minor impact compared to the triggering criteria for emergency alerts but if it cannot be excluded due to the condition of the installation that other effects may occur that meet the triggering criteria for an emergency alert.
- An **emergency alert** is triggered if a hazardous release of radioactive substances into the environment is detected or threat thereof in the event of an accident at the nuclear installation.

The licence holder's alarm regulation contains the relevant plant-specific emission and immission criteria as well as technical criteria for an early warning and emergency alert. If these are reached, the licence holder will alert the disaster control authorities, indicating the corresponding stage of alert, the competent supervisory authority and the RLZ. Here, the technical criteria, e.g. very high temperature of low level in the reactor pressure vessel (RPV), are of special relevance as they are early indicators of a violation of protection goals and require early warning.

To cope with emergencies, the licence holder establishes a crisis management team. The individual organisational regulations are described in a separate document, the NHB (→ Article 19 (iv)). Specifications regarding the content and structure of the NHB are compiled in safety standard KTA 1203 “Requirements for the Emergency Manual” (→ Article 7 (2i)). In their entirety, the regulations mentioned, especially the alarm regulations, the NHB, the accident mitigation manual (HMN) (→ Article 18 (i)) as well as the training and further qualification programme represent the licence holder's emergency plan, which includes i.a.

- measures to render the emergency organisation operable,
- criteria for alerting the competent authorities,
- technical measures for the prevention and mitigation of damages,
- measuring programmes for determining the radiological situation,
- measures for efficient communication and cooperation with external parties, such as the competent authorities, and for informing the population.

Assistance is provided by the crisis management team of the plant manufacturer and by the Kerntechnischer Hilfsdienst GmbH (KHG, an organisation jointly installed by the licence holders of all German nuclear installations). The crisis management team of the manufacturer advises the licence holder in technical questions regarding an assessment of the situation and the restoration of a safe condition of the installation, while the KHG with its manipulators and measuring equipment may be employed at the site inside and outside the installation. In addition, there are mutual support agreements between the licence holders of the nuclear installations.

Off-site emergency plans

As defined in the StrlSchG, the competent disaster control authorities draw up off-site emergency plans for the vicinity of fixed installations or facilities with special hazard potential, in particular for nuclear installations, in accordance with the relevant provisions under *Land* law. They continuously update the plans and review them at regular intervals (on principle annually). The primary objective of disaster control planning is to prevent or mitigate direct consequences from the impact of an accident on the population in the event of an accidental release. Until the adoption of the general and special emergency plans of the Federation and the *Länder* provided for in the StrlSchG, the content of the plans is based on the basic recommendations[20] that provisionally continue to apply as emergency plans. The off-site emergency plans focus on the interaction of the planning of the authorities and measures of the licence holder as well as on the implementation of measures to protect the population. The planning also includes the necessary measurements for determining the situation.

For foreign nuclear installations which, due to their location close to the border, may require short-term emergency management measures on German territory, emergency planning is carried out in the same way and in coordination with the neighbouring countries concerned.

For initial medical care and decontamination of the population and the emergency workers affected by a release, emergency care centres are provided. The regulations for their construction and operation as well as the list of physicians who are available for service in emergency care centres are maintained by the responsible *Länder*.

[20] SSK recommendation “Rahmenempfehlung für den Katastrophenschutz in der Umgebung kerntechnischer Anlagen”, adopted at the 274th meeting of the SSK on 19/20 February 2015

The catalogue on assistance possibilities in the event of nuclear accidents published by the BMU is a continuously updated list of consultants, nuclear installations, measuring organisations and regional radiation protection centres and is made available to the competent authorities if such an event occurs in order to request additional assistance from those listed beyond existing precautions.

The emergency plans of the Federation and the *Länder* cover many other areas such as the production and supply of drinking water, the production of plant and animal products, food, feed, pharmaceuticals and their raw materials, other products, objects and substances, the transport of goods, the cross-border movement of persons, vehicles, goods and luggage, the handling of contaminated areas and the management of waste and waste water.

Situation assessment

For accidents in nuclear installations and all other emergencies which may have not only local, but also regional or transregional effects, the StrlSchG provides for drawing up a uniform RLB. This is decisive for the assessment of the radiological situation for all authorities of the Federation and the *Länder* that have to decide on appropriate measures in this emergency. The RLB prepares, presents and radiologically assesses all relevant information available at the respective point in time on the nature, extent and expected further development of the radiological situation. Easily comprehensible, diagnostic or prognostic representations are provided for the responsible authorities. The authorities have to decide on the appropriate protective measures at short notice without any in-house radiological expertise. The representations are, in particular, maps showing in which areas the dose levels, triggering criteria, limit or guideline values defined in advance as radiological criteria for certain protective measures in the ordinances and emergency plans of the Federation have already been met or at which point in time they may be exceeded there. This information is made available to the participating organisations in a standardised data format. The RLB is transmitted to all competent bodies in order to create a uniform knowledge base which is updated at regular intervals. On the basis of this radiological assessment, the federal or *Land* authorities responsible for the respective subject area can then decide whether these measures are appropriate, taking into account all non-radiological decision criteria, in particular the damage and other detriments that may result from the protective measures in the event of an emergency, and whether they can be implemented in good time with the available human and material resources on the basis of the legal provisions applicable to the respective area.

The assessment of the situation is performed with the available information about the plant state, the meteorological position and the emission and immission situation. It is initially based on automatic measurements and forecasts. Later, additional measurements in the surrounding area will become increasingly important. In 2014, the SSK developed requirements for the forecast and estimation of source terms in the event of nuclear power plant accidents[21] based on the lessons learned from the Fukushima nuclear accident within the framework of a recommendation. A supplement to this recommendation is currently being prepared.

In the pre-release phase, the radiological situation to be expected in the vicinity of the nuclear installation is estimated on the basis of forecast data of the source term based on a PSA (probabilistic safety analysis) or plant parameters as well as the meteorological situation. For this purpose, the Real-Time Online Decision Support System) (RODOS), operated centrally by the BfS is used, where appropriate in combination with the KFÜ of the *Land* or *Land*-specific systems (→ Article 15). RODOS can be used to calculate local, regional and transregional impacts of releases as well as the effect of protective measures, thus providing information about the situation and impact assessments within the framework of the RLB as a decision-making aid for the competent authorities. The licence holder provides the prognostic source term data for the most probable accident scenario and

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21 SSK recommendation “Prognose und Abschätzung von Quelltermen bei Kernkraftwerksunfällen”, adopted at the 270th meeting of the SSK on 17/18 July 2014

a worst case scenario, based on his situation assessment. Meteorological data required for the systems result from the data measured at the site with the KFÜ or the *Land*-specific systems as well as from the numerical weather forecasts of the German meteorological service Deutscher Wetterdienst.

During the release, the licence holder is to determine the source term on the basis of plant-specific, radiological and, if applicable, meteorological information. Additional data from the KFÜ or the *Land*-specific systems may also be available. For the assessment of the radiological situation in this phase, there are furthermore data available from the local dose rate probes of the KFÜ installed in the near-field of the nuclear installation or from the *Land*-specific systems, from the IMIS and, as the case may be, also first data of survey teams. The RODOS decision support system described above is also used here. As soon as data of the measurements according to the measurement programmes provided are available s (→ Figure 16-3), the predicted situation is checked and adapted to the situation determined by measurements.

In the post-release phase, the measuring and sampling services of the licence holder and of the authorities provide data – in accordance with the provisions of the REI (Guideline on Emission and Immission Monitoring of Nuclear Installations) and the provisions of the general emergency plan of the Federation – for determining the radiological situation, which are supplemented by follow-up measurements carried out by radiation detection teams (emergency workers of the disaster control authorities) and the BfS. The soil contamination in the wider area surrounding the nuclear installation as well as the identification of areas with increased dose rates (hot spots) is shown by means of mobile measurements (e.g. aero-gamma spectrometry or vehicle-based measurements). The RLZ is responsible for the overall coordination of the measuring services.

The areawide development of the radiological situation in Germany is determined and presented by means of the IMIS.

The need to inform a large number of authorities and organisations about the current situation in the case of a radiological event at short notice and effectively has led to the nationwide introduction of the electronic situation display for emergency preparedness (ELAN), which provides the RLB with Internet-based information and, if required, further data and information for the competent authorities and the organs and organisations connected to the system.

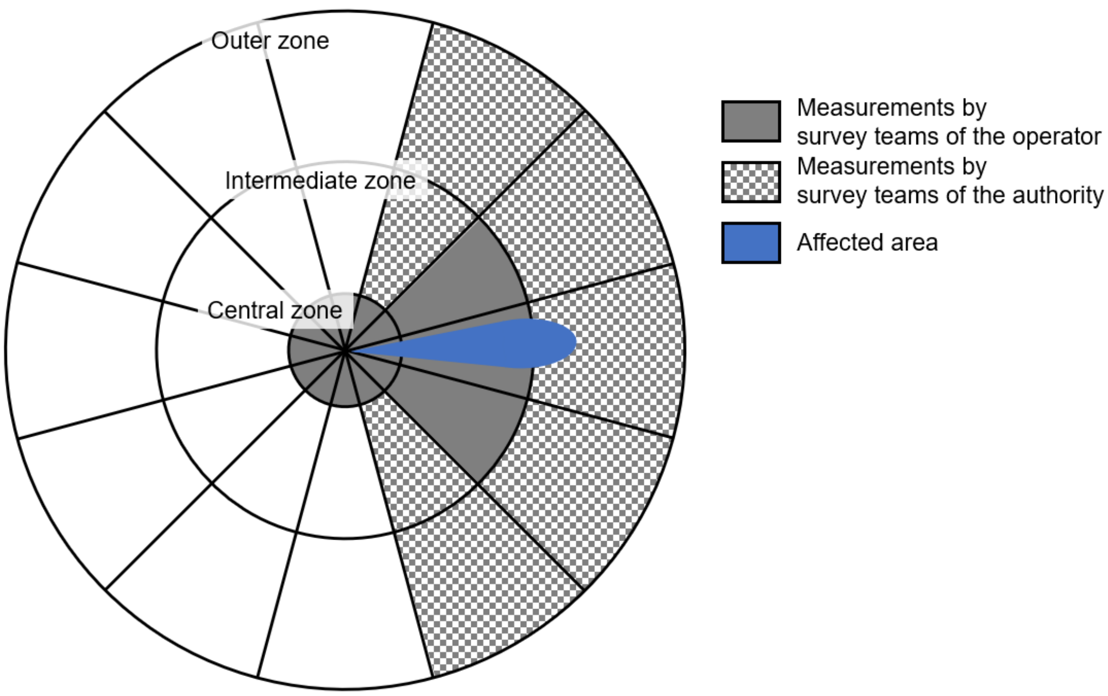

Figure 16-3 Deployment areas of the different measuring and sampling teams

Criteria for emergency management measures

The StrlSchG defines reference levels for the protection of the population and the emergency services as overriding generic criteria for measures (→ Table 15-1). Emergency workers are all persons having a defined task in an emergency while taking action in response to the emergency, e.g. as plant personnel, public security and rescue services (e.g. police, fire brigade, paramedics, physicians) or the workers deployed for certain tasks within the framework of emergency response (e.g. measurements, transports, repairs, construction work).

In addition, triggering criteria in the form of dose rate limits or surface contamination limits, referred to as operational intervention levels (OILs), are to be defined for the emergency management measures, which are to be used as decision-making aids for ordering of protective measures and behavioural recommendations for the population. The following objectives apply when defining these criteria and the final decision on measures:

- Severe deterministic effects shall be avoided by measures for limiting the individual radiation dose to limits below the threshold doses for these effects.
- The risk of stochastic effects for individuals shall be reduced by appropriate measures.
- The measures shall provide more benefits than harm for the persons affected.

Recommendations from publications 103 and 109 of the ICRP (International Commission on Radiological Protection), the IAEA's Basic Safety Standards[22], Directive 2013/59/Euratom[23] and lessons learned from the Fukushima nuclear accident were taken into account in these specifications. For a rapid implementation of short-term emergency management measures in the early phases of a release event that is occurring, has already occurred or where there is a threat thereof, dose levels[24] are specified which ensure compliance with the reference level of the remaining dose in the first year. The reference level of the remaining dose in the first year is decisive for radiological decision criteria on protective measures in medium- and long-term emergency management.

The SSK was commissioned to draw up proposals for radiological criteria for the lifting of emergency management measures. Such criteria are provided for by law as part of the general emergency plan of the Federation. According to §§ 109 and 111 StrlSchG, the criteria and procedures for the lifting of protective measures shall take into account the effectiveness of the measures already taken, the dose that affected population groups have already received and are likely to receive (dose estimate), changes in the radiological situation and other circumstances of the emergency. As a criterion for an end of the emergency exposure situation and a possible transition to an existing exposure situation, it is specified that it shall be ensured that an effective dose of 20 mSv per year for the affected population is not exceeded.

Table 16-1 contains the dose levels specified in the NDWV for certain early disaster control measures, which were derived from the legal reference level assuming continuous stay outdoors without clothing.

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[22] "Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards", IAEA Safety Standards Series No. GSR Part 3, 2014

[23] Council Directive 2013/59/Euratom of 5 December 2013, Official Journal of the European Union L 13/1, 17 January 2014

[24] NDWV, promulgated as Article 2 of the "Verordnung zur weiteren Modernisierung des Strahlenschutzrechts" of 29 November 2018 (Federal Law Gazette I p. 2034); entry into force pursuant to Article 20(1) p. 1 of this ordinance on 31 December 2018

Table 16-1 Dose levels for early protective measures

Measure	Organ equivalent dose (thyroid)	Effective dose	Explanations on integrations periods and exposure paths
Sheltering		10 mSv	Sum of effective dose from external exposure within seven days and committed effective dose from radionuclides inhaled during this period, assuming staying outdoors without taking protective factors into account
Taking iodine tablets	50 mSv children and teenagers under age 18 and pregnant women 250 mSv individuals aged 18 to 45		Committed equivalent dose (thyroid) from radio-iodine inhaled within seven days, assuming staying outdoors without taking protective factors into account
Evacuation		100 mSv	Sum of effective dose from external exposure within seven days and committed effective dose from radionuclides inhaled during this period, assuming staying outdoors without taking protective factors into account

Short-term emergency management measures in the affected area

Off-site emergency planning refers to the preparation and implementation of measures to protect the population from the effects of radionuclide releases resulting in contamination and increased exposure. As a priority for the implementation of these objectives, the following short-term measures

- sheltering,
- taking potassium iodide tablets (iodine tablets), also referred to as iodine thyroid blocking,
- evacuation, and
- restrictions on the consumption of fresh, locally produced food,

are provided, where appropriate, with supplementary and accompanying measures (e.g. distribution of iodine tablets). The dose levels specified in the NDWV (→ Table 16-1) are to be used as radiological criteria for the adequacy of the three protective measures mentioned therein.

Planning areas for the above measures are based on risk analyses of the BfS. These risk analyses take into account the potential effects of an accident. The indicated boundaries of the individual zones are graded according to the hazard potential and are to be adapted to the respective local conditions. The planning radii of nuclear installations are specified with corresponding measures in Table 16-2. For nuclear installations that are to be decommissioned, the planning radii for power operation shall be maintained as long as there is still nuclear fuel in the installation, but for no longer than three years from the day of the last shutdown. Thereafter, the radii for decommissioned nuclear installations will apply. The arrangements for iodine thyroid blocking are to be maintained for a period of one year from the date of the last shutdown. The times specified for the measure “evacuation” apply from the date of alerting.

Table 16-2 Planning radii for nuclear installations

Nuclear installation	Zone	Radius	Pre-planned measures
Nuclear installations in power operation Nuclear installations to be decommissioned with spent fuel in the first three years from the date of the last shutdown	Central zone	5 km	Sheltering Iodine thyroid blocking Evacuation within 6 h
	Intermediate zone	20 km	Sheltering Iodine thyroid blocking Evacuation within 24 h
	Outer zone	100 km	Sheltering Iodine thyroid blocking
		up to 200 km	Iodine thyroid blocking for children, teenagers and pregnant women
Decommissioned nuclear installations	Central zone	2 km	Sheltering Evacuation within 6 h
	Intermediate zone	10 km	Sheltering Evacuation within 24 h
	Outer zone	25 km	Sheltering
Research reactors	Central zone	2 km	Sheltering Iodine thyroid blocking Evacuation within 24 h
	Intermediate zone	8 km	Sheltering Iodine thyroid blocking
	Outer zone	20 km	Sheltering Iodine thyroid blocking for children, teenagers and pregnant women

Instruction sheets on the use of iodine tablets are contained in the SSK recommendation “Use of iodine tablets for thyroid blocking following a nuclear accident”. In particular, the SSK recommends that physicians and pharmacists in potential distribution areas obtain iodine instruction sheets and information about iodine thyroid blocking to be able to advise patients in advance on how to behave individually in case an event occurs.

In addition, comprehensive information is available to the population in connection with the taking of iodine tablets, which can be downloaded from the Internet at www.jodblockade.de.

In the event of rapidly developing events with imminent core meltdown, short-term initiation of measures to protect the population (warning the population, sheltering, taking of iodine tablets) in the area of the central zone and the intermediate zone has been specified.

In addition to these measures, a precautionary warning against the consumption of freshly harvested contaminated foodstuffs is issued to prevent incorporation doses This measure will be adapted to the current situation as soon as corresponding data from measurements are available. Beyond that, the further measures are to be included into the planning:

- warning and informing the population,
- controlling, regulating and restricting road traffic,
- establishment and operation of emergency care centres,
- decontamination and medical care of the deployment personnel affected,

- initiating traffic restrictions for rail, waterway and, where required, air traffic,
- informing the water catchment and distribution bodies,
- closing contaminated water catchment points,
- warning the population against using water and against aquatic sports and fishing,
- informing waterway traffic,
- closing heavily contaminated areas,
- ensuring food supply,
- ensuring water supply,
- providing the animals with feed, in special cases relocation; where required, culling and disposal of heavily contaminated animals,
- decontaminating traffic routes, houses, equipment and vehicles,
- banning the circulation of contaminated foodstuffs and feedstuffs.

Medium- and long-term emergency management measures

Medium- and long-term emergency management measures serve to reduce the exposure of the population also in areas where the short-term measures for hazard prevention by disaster control are not or no longer justified. These include i.a.

- measures in the form of behavioural recommendations for the population,
- measures in the agricultural sector to prevent or reduce contamination of agricultural products and agricultural land,
- decontamination measures,
- measures to prevent the placing on the market of contaminated products, and
- measures for the management of waste and waste water.

On-site measures

The procedures to be applied by the licence holders of the nuclear installations in the event of anticipated operational occurrences, design basis accidents and emergencies are described in Article 19 (iv). Measures to reduce the frequency of occurrence of accidents with severe fuel damage (preventive emergency measures) or measures to mitigate the consequences of accidents with severe fuel damage (mitigative emergency measures) were implemented during the construction of the nuclear installations or retrofitted at existing nuclear installations. They are described in Article 14 (i) and Article 18 (i).

Exercises

In order to be able to successfully implement the necessary protective measures in the case of an event, great importance is attached to emergency response exercises of the licence holder and the competent authorities as well as to the on-site and off-site training of emergency workers.

Exercises conducted by the licence holder of a nuclear installation

The measures provided by the licence holder are trained, reviewed and further developed by regular exercises. Exercises involving all organisational units involved in the licence holder’s emergency organisation are generally performed once a year per nuclear installation in accordance with the general guidelines for emergency planning by nuclear power plant operators[25].

In order to be able to conduct exercises as realistically as possible, the accident scenarios on which the exercises are based are usually worked out in great detail. Typical exercise scenarios are events with loss of coolant, events with external hazards, events with anticipated transient without scram (ATWS) and station blackout events. These events are combined with insufficient core cooling or residual heat removal or insufficient containment isolation in order to simulate design extension conditions according to the objectives of the respective exercise. Furthermore, events in the field of physical protection are also included in the licence holder's exercise programme. The exercises are carried out in the nuclear installations as realistically as possible, also making increasingly use of the power plant simulators for exercise scenarios with nuclear installations.

The annual exercises are generally limited to the sites of the nuclear installations. At larger intervals, the interaction with the manufacturer's crisis management team, the KHG and the authorities responsible for off-site emergency planning is practised.

The competent authorities are informed about on-site exercises and often take part themselves in order to simultaneously practise the procedures within their own emergency organisation. This co-operation is flanked by supervisory inspections, e.g. on supervisory focal points on the part of the nuclear licensing and supervisory authority at the site. On the part of the licence holders, exercises are presented and discussed within the scope of the exchange of experiences and feedback, e.g. on VGB working panels. Exercises carried out by other nuclear installations at other sites are also observed.

In addition to exercises with the participation of the nuclear licensing and supervisory authority and the authorised experts, there are also on-site management exercises including the interfaces with disaster control. Among other things, exercises were carried out on

- fire protection,
- availability,
- plant security and physical protection (other third-party intervention),
- design extension condition during shutdown,
- the crisis management team, and
- the medical and rescue services.

Some of these exercises took place on simulators, also including the situation centre and the KFÜ of the *Land*.

Exercise reports on the course of the on-site exercises and essential lessons learned are incorporated into emergency planning and are attached to the documents related to emergency response. The personnel receive feedback in training measures. The documentation on emergency response is regularly reviewed for completeness and correctness.

Off-site exercises

As defined in the StrlSchG, the authorities and organisations involved in emergency response pursuant to the emergency plans of the Federation and the *Länder* as well as those responsible for the education and further training of the emergency workers regularly conduct emergency exercises. These emergency exercises shall be differentiated appropriately according to the type of exercise,

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25 Recommendation of the SSK and the RSK "Rahmenempfehlungen für die Planung von Notfallschutzmaßnahmen durch Betreiber von Kernkraftwerken", adopted at the 242nd meeting of the SSK on 1/2 July 2010 and at the 249th meeting of the RSK on 14 October 2010, amendment adopted at the 468th meeting of the RSK on 4 September 2014 and at the 271st meeting of the SSK on 21 October 2014

scope, emergency scenarios and participants. In particular, the following shall be tested and practised:

1. the organisational arrangements for emergency response, and
2. the exchange of information and the cooperation of the authorities, organisations and radiation protection executives involved in emergency response in accordance with the emergency plans in the following cases:
   a) determination and assessment of the situation,
   b) coordination of the decisions of the competent authorities and
   c) implementation of appropriate protective measures.

The disaster control authorities at *Länder* level and regional level regularly conduct disaster control exercises at the sites of nuclear installations, albeit at intervals of several years due to the considerable effort and expenditure involved. In addition to the competent authorities and the technical advisory bodies, the licence holder of the installation also participates in these external exercises. Usually, the potentially affected population does not take an active part in these exercises.

The objectives of such exercises include improving communication and cooperation between the various bodies and organisations involved in emergency management and ensuring effective work in emergency preparedness and response. Further exercise objectives are the practical deployment of forces within the framework of measuring tasks and special support services, such as the testing of temporarily set up emergency care centres to provide information on decontamination measures and medical care for the population.

An exercise scenario focusing on off-site measures is usually developed by the authority, in order to exercise the main tasks of the team in disaster control management. This includes, in particular, the evaluation of the RLB, the type and scope of measures, the management of the emergency workers and the provision of information to the population.

While the focus of the exercises performed so far has been on a scenario with postulated release of radioactive substances into the environment without considering the actual accident sequence in the installation itself, there is a tendency to increasingly hold site-specific, so-called integrated exercises. In these exercises, the licence holder and the competent authorities of potentially affected *Länder* simulate a plant-specific scenario. These exercises are aimed at integrating the processes developing in the installations and practicing the associated cooperation and communication between the licence holders and the competent authorities.

To improve disaster control measures, the main emphasis of the exercises is, on the one hand, on systems that are based on the use of modern information technologies. These include, for example, a joint measuring centre, a management and information system for disaster control data or an ELAN with a corresponding communication concept. On the other hand, the exercises are increasingly geared towards the overall cooperation between the different organisations that are assigned to control an accident.

Off-site exercises with international participation

As part of international cooperation and on the basis of bilateral agreements, representatives of authorities from neighbouring countries are actively involved, or participate at least as observers, in exercises of nuclear installations near the border.

In the years 2017 and 2018, the RLZ participated in two French emergency exercises in the form of command post exercises together with command posts of the *Länder* participating in the respective exercise. From a German perspective, these exercises focused on the communication and coordination procedures between the national regulatory structures, the communication with the neighbouring countries and a test of the alarm routes from the licence holder of the nuclear installation to the German authorities involved. The exercise scenarios were nuclear accidents in the French nuclear installations Cattenom and Fessenheim, which are close to the German border. The exercise scenarios had been developed by France.

On principle, the regular exercises of the EU (ECURIE exercises), the IAEA (CONVEX) and the OECD/NEA (Organisation for Economic Co-operation and Development/Nuclear Energy Agency) (INEX) are attended by RLZ staff according to their responsibilities. In addition, depending on the exercise situation, supporting bodies, other federal ministries and the competent nuclear licensing and supervisory authorities of the *Länder* are also involved.

In order to further develop and harmonise nuclear emergency preparedness internationally at a sufficiently high level, representatives of the BMU and experts working on behalf of the BMU participate for Germany in the relevant bodies of the OECD/NEA, IAEA and EU as well as in the Working Group Emergencies (WGE), the Heads of European Radiation Control Authorities (HERCA) of the European association of regulators in the field of radiation protection.

Regulatory review

On-site regulatory review

The topic “emergency provisions” is an independent inspection area and includes i.a. the control of the preparation, execution and evaluation of emergency exercises carried out by the licence holders. This is regularly reviewed by the nuclear licensing and supervisory authorities.

External reviews

Like the other emergency plans of the Federation and the *Länder*, the off-site emergency plans for fixed installations or facilities with special hazard potential are regularly reviewed with regard to changes in the state of the art in science and technology, experience feedback from emergency exercises and lessons learned from emergencies in Germany or abroad and, if necessary, adapted by the competent authorities and organisations.

16 (2) Informing the population and neighbouring countries

Informing the population

The population is to be informed by the competent authorities and the licence holders of nuclear installations. The main contents of this information are specified in the StrlSchG and the StrlSchV. As defined by law, the competent federal authorities publish the federal emergency plans. In addition, the population is actively and systematically informed about the protective measures and other essential elements of the emergency planning relevant to it and receives recommendations on how to behave in the event of possible emergencies. In this respect, a distinction is made between the information to be provided to the population in preparation for an emergency and the relevant information in an actual emergency.

Informing the population as an emergency preparedness measure

The main issues about which the population needs to be informed in advance are i.a.

- basic terms of radioactivity and effects of radioactivity on humans and the environment,
- the emergencies taken into account in emergency planning and their consequences for the population and the environment,
- planned measures to alert and protect the population, and
- recommendations on how to behave in possible emergencies.

This is realised through information on websites and brochures. The relevant information page of the nuclear licensing and supervisory authorities is the information portal of the Federation and the *Länder* published by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) at https://www.nukleare-sicherheit.de, which also contains links to other websites, such as the one on iodine thyroid blocking and the brochure Guide for Emergency Preparedness and Correct Action in Emergency Situations of the Federal Office of Civil Protection and Disaster Assistance (BBK). The licence holders produced brochures which were sent to households in the vicinity of the installations and which can be downloaded from their websites. The information intended to protect the public and the way in which the information is to be provided, repeated and updated is to be agreed with the competent disaster control authorities.

The information and behavioural recommendations of the competent authorities of the Federation and the *Länder* are also to be updated regularly and in the case of significant changes and published in an updated version without any request being made. They must be permanently accessible to the public.

Informing the population as an emergency response measure

In the case of a safety-relevant event in a nuclear installation which may or will lead to an emergency in the surrounding area, the competent authorities inform the potentially affected population immediately and recurrently in accordance with the legal requirements of the StrlSchG and give recommendations for behaviour including precise instructions for measures to be taken. The information to be given to the population includes i.a.

- type and characteristics of the emergency, in particular its origin, dispersion and anticipated development,
- behavioural recommendations (e.g. staying indoors, consumption restrictions) and warnings for certain population groups, and
- the recommendation to follow the instructions and appeals by the competent authorities.

The first alarming of the population can take place by means of the modular warning system (MoWaS) of the BBK. This system can also be operated in the core network in the event of a failure of the public power supply or the Internet. A person responsible for civil protection can immediately trigger all alarm and warning systems in his area of responsibility at the same time. These systems include, for example, mobile phones, pagers, radio, television, digital advertising boards and, in the future, other terminal devices such as sirens, the digital radio DAB+ or public transport display boards. The federal emergency information and message app, Warn-App NINA for short, is connected to MoWaS and is one of several warning apps that are supplied. The Warn-App NINA, for example, can be used to quickly and efficiently issue warning messages and emergency tips on smartphones. The RLZ is equipped with a MoWaS terminal for emergencies. In addition, the warning system can be used by all situation centres of the *Länder* and many already connected control centres of cities and municipalities (lower disaster control authorities). The technical basis for MoWaS was further developed from the federally owned satellite-based warning system (SatWaS) designed for civil protection. Currently, there are about 106 authorised MoWaS stations connected to the secured core network in Germany. Via web-based access, there are another 130 stations in the network, which are however dependent on the function of the Internet.

For example, the following information and instructions are to be given to the population in the case of an early warning level (pre-alarm):

- request to turn on radio and television,
- preparatory instructions for certain institutions, and
- recommendations for particularly affected professions.

In addition to regulations governing responsibilities, there are procedures according to which the various institutions involved coordinate the content of their information. Furthermore, it is specified how citizens can contact the authorities responsible for disaster control and which media are used to inform the public. Model texts for informing the population are laid down in the General Guidelines[26]. The suitability of the prepared measures for informing the public is re-appraised in the exercises.

As defined in the StrlSchG, the authorities and organisations involved in decisions on protective measures or their implementation cooperate in the event of an emergency in accordance with the emergency plans. Decisions and protective measures, including behavioural recommendations, shall be coordinated to the extent necessary, provided that they do not prevent or unduly delay the timely implementation of adequate protective measures. The RLZ is responsible for coordinating the protective measures and the measures to inform the population within the Federal Government and with the *Länder* as well as with foreign states, the EU and with international organisations.

Informing neighbouring countries

As defined in 2013/59/Euratom, EU Member States shall cooperate with other Member States and with third countries in addressing possible emergencies on its territory which may affect other Member States or third countries, in order to facilitate the organisation of radiological protection in those Member States or third countries. To this end, the StrlSchG stipulates that the authorities responsible for drawing up emergency plans shall, within the framework of their competences and in accordance with the principles of reciprocity and equivalence with third countries, endeavour to coordinate their emergency plans with other Member States of the EU and the Euratom to the extent necessary to prepare a coordinated emergency response. In Germany, the RLZ is responsible for the exchange of information on the radiological situation and its assessment with foreign states, the EU and international organisations as well as the coordination of protective measures and measures for information, unless other competence is established by law or pursuant to a law.

The measured data acquired by the monitoring programmes and the situation assessments submitted by the licence holder form the basis for the RLB in an emergency exposure situation. The RLB forms the basis for reporting in accordance with the EU arrangements for the early exchange of information and the Convention on Early Notification of a Nuclear Accident and also serve as a basis for the exchange of information for the fulfilment of bilateral agreements. This ensures that Germany's neighbouring countries will receive timely information.

Germany has signed bilateral agreements on mutual assistance in the event of disaster situations with all nine neighbouring countries. In addition, corresponding assistance agreements have been concluded with Lithuania, Hungary and the Russian Federation. Due to such agreements, there are direct information and data exchange channels at regional level at the sites of nuclear installations close to the border between the disaster control authorities competent for these installations or the

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[26] SSK recommendation “Rahmenempfehlungen für den Katastrophenschutz in der Umgebung kerntechnischer Anlagen” (General Guidelines for emergency response in the vicinity of nuclear installations), published in BAnz AT 04.01.2016 B4

organisations responsible for determining the radiological situation and the authorities of the neighbouring country.

Other cross-border collaboration activities with neighbouring and other countries on nuclear safety is dealt with under Article 17 (iv).

16 (3) Emergency preparedness of contracting parties without nuclear installations

Not applicable to Germany.

Progress and changes since 2017

During the review period (2017 - 2019), numerous amendments and revisions of regulatory documents in the field of emergency preparedness were carried out, based in particular on the experience gained from the reactor accidents in Fukushima and the transposition of Directive 2013/59/Euratom into German law. Particularly important in this context are

- the StrlSchG,
- the NDWV, and
- the StrlSchV.

The legal and administrative framework for emergency preparedness and response was further developed within the framework of the provisions of the StrlSchG on the emergency management system of the Federation and the *Länder* in order to ensure coordinated action by all authorities and organisations involved in emergency response on the basis of the optimised protection strategy determined in advance in the emergency plans and to ensure a uniform assessment of the radiological situation. The ministries and authorities of the Federation and the *Länder* that perform hazard prevention tasks in everyday business or other crisis situations in a specific area of life or economic sector (e.g. in disaster control, medical care, food and feed safety) generally retain this responsibility in the event of radiological emergencies and use proven legal bases, administrative structures, personnel resources, facilities and precautions also for radiological emergency protection.

To further develop technical and organisational cooperation for coping with emergencies, the RLZ was set up as a new institution within the emergency management system of the Federation and the *Länder*. The RLZ established at the BMU, as the supreme federal authority responsible for radiation protection, prepares an RLB in the event of emergencies in nuclear installations which may have transboundary or transregional effects within the territory of the Federal Republic, i.e. a report with a technically sound preparation, presentation and evaluation of the information on the type, extent and expected development of the radiological situation. This includes, in particular, maps showing in which areas the dose levels, contamination levels or other OILs are exceeded that are specified in the NDWV and the federal emergency plans as radiological criteria for the adequacy of certain protective measures. In addition, the RLZ is responsible in particular for the coordination of protective measures and measurements.

17 Siting

ARTICLE 17 SITING

Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

i) for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;

ii) for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;

iii) for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation;

iv) for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.

17 (i) Site evaluation

Since § 7(1) of the Atomic Energy Act (AtG) stipulates that in Germany no further licences shall be granted "for the construction and operation of installations for the fission of nuclear fuel for the commercial generation of electricity", this section on Article 17 is confined to the design requirements of the nuclear installations and the periodic re-assessment of the site characteristics as part of the Safety Review (SÜ). For the German nuclear installations, the requirements of national nuclear rules and regulations applicable at that time with regard to external hazards, in particular earthquake, flood, aircraft crash and blast waves were considered in the design. Within the framework of the SÜ to be carried out every ten years, the national nuclear rules and regulations applicable at the time of the review serve as a basis for the assessments.

Procedures and criteria for site selection

Criteria for the evaluation of sites for nuclear power plants that are to be applied in a uniform manner throughout Germany are described in "Data for the Evaluation of Site Properties for Nuclear Power Plants". These contain essential aspects concerning the suitability of the site regarding regional planning as well as to nature conservation and landscape conservation. With respect to nuclear safety, the following issues have, amongst others, been taken into account:

- meteorology with regard to atmospheric dispersion conditions,
- hydrology with regard to cooling water supply, the discharge of radioactive substances via the water path and the protection of drinking water supplies,
- distribution of population in the vicinity of the site,
- geological condition of the building ground, including seismological assessments of the site,
- other natural or man-made external hazards (i.a. flood, aircraft crash, blast wave, intrusion of hazardous substances),
- road transportation infrastructure with regard to site accessibility, and
- distance to military installations.

Design against man-made and natural external hazards

The requirements for the construction of the German nuclear installations relating to the design and the protective measures against external hazards followed the provisions of the national nuclear rules and regulations applicable at that time. In the cases where the national nuclear rules and regulations did not contain detailed provisions yet, specific requirements were defined in the respective licensing procedure. The steps in developing the requirements are described below. The re-evaluation of nuclear installations relevant in this context is dealt with in Article 17 (iii).

All nuclear installations at sites subject to such hazards were not only designed against natural external hazards, such as wind and snow, but also against flood and earthquake. In this respect, both nuclear safety standards and conventional civil engineering standards were applied. There are also additional safety requirements depending on the design of the cooling water supply to the emergency core cooling and residual heat removal system of the installation. Depending on the respective site conditions, it was demonstrated, where applicable, that the cooling water supply is ensured even under unfavourable conditions, such as low water in the river or failure of a river barrage.

Design against flooding

The requirements for flood protection measures due to high river runoff rates and storm surges are included in safety standard KTA 2207 "Flood Protection for Nuclear Power Plants". According to this standard, permanent flood protection measures must always be provided. Under special boundary conditions, protection against the difference between the water levels of the flood with an exceedance probability of 10^{-2}/a and the design water level of 10^{-4}/a may also be provided by temporary measures.

The sites of nuclear installations are mostly located inland at rivers and, in some cases, at estuaries with tidal influences. In most of the cases, sites have been selected which are located sufficiently high. In all other cases, the safety-relevant structures were sealed for water tightness and built with waterproof concrete. Furthermore, openings (e.g. doors) are located above the level of the highest expected flood. In some cases, the flood protection concept also includes dikes. If these permanent protective measures should not be sufficient, mobile barriers are available to close openings.

In 2016, the flood protection requirements were supplemented by a statement of the Reactor Safety Commission (RSK)[27] to the effect that the uncertainties in the determination of the design basis flood are to be systematically recorded and evaluated. With regard to epistemic uncertainties, this shall be done by applying different methods for the determination of the design basis flood and by comparing the results. In addition, the calculation result achieved shall also be compared with historical flood events in the region.

Design against earthquake

Since 1990, the design against earthquakes has been based on a design basis earthquake (formerly "safe shutdown earthquake") in accordance with safety standard KTA 2201.1 "Design of Nuclear Power Plants against Seismic Events; Part 1: Principles". The so-called operating basis earthquake, formerly to be considered additionally according to the previous version of 1975, was replaced by an "inspection level", beyond which the plant state is to be checked. Since entry into force of the latest version of KTA 2201.1 in November 2011, the design basis earthquake is determined on the basis of deterministic and probabilistic analyses (As specified in the earlier versions of KTA 2201.1, it was determined purely deterministically.). For both methods, wider surroundings of the site (with a radius of at least 200 km) have to be considered. The deterministic determination of the design basis earthquake is to be based on an earthquake with the maximum seismic impact assumed for the site – taking into account events that have occurred in the past – that can be expected according to scientific knowledge. The probabilistic determination of the parameters of the design basis earthquake has to take an exceedance probability of 10^{-5}/a (median) into account. The design basis earthquake will then be conclusively defined taking into account the results of both analyses. Depending

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[27] RSK statement "Aspects of the determination of the site-specific design basis flood" adopted at the 481st meeting of the RSK on 10 February 2016

on the site, the intensity of the design basis earthquake lies between VI (minimum design for sites with low seismic risk) and a maximum of VIII (Medvedev-Sponheuer-Kárník-Skala (MSK scale)).

The structures, components and plant components of the nuclear installations of older construction lines that are no longer in power operation were partly designed using simplified (quasi-static) methods and the resulting design specifications. Within the framework of the SÜ, additional dynamic analysis methods were also used for these installations for reassessment purposes.

Protection against aircraft crash

Protection against aircraft crash refers to the accidental crash of an aircraft on safety-relevant areas of a nuclear installation. The protective measures were implemented against the background of the increasing number of nuclear installations in Germany in the 1970s and a high crash rate of military aircrafts in those years. The general basis was the analysis of the crash frequency (the exceedance probability for impacts on safety-relevant buildings is about 10^{-6}/a and per nuclear installation) and of the loads on the reactor building that would be caused by such a crash. From the mid-1970s onwards, load assumptions were developed for the impacts of a crash of a fast-flying military aircraft, which were used for the design of protective measures for the nuclear installations built in the following years for further risk minimisation. The requirements relating to the protection against aircraft crash included in the “Safety Requirements for Nuclear Power Plants” are based on the recommendations of the RSK of 1981. As load assumption, a site-independent impact load-time diagram corresponding to the impact of a fast-flying military aircraft of the “Phantom” type (mass 20 t, speed 215 m/s) on a rigid wall is specified. It was furthermore specified, amongst other things, that the impacts of debris and of kerosene fires as well as the vibrations induced by the impact of the aircraft have to be taken into account in the design. However, since the late 1980s, the crash rate of fast-flying military aircraft has decreased significantly so that the crash frequency today can be assumed to be smaller by about two orders of magnitude.

For older construction lines no longer in power operation, protection by system design against the consequences of an aircraft crash was improved by additional auxiliary emergency systems physically separated from the actual reactor building. The second-level emergency systems can ensure compliance with the protection goals (“reactivity control”, “fuel cooling” and “confinement of radioactive material” (→ Article 19 (iv)) even if important plant components are destroyed due to external hazards. The spatial arrangement of the buildings ensures that the safety systems and equipment located in the central reactor area and in the second-level emergency systems do not become inoperative due to the postulated events at the same time. The scope of protection of these nuclear installations against aircraft crashes was demonstrated by subsequent reviews of the design margins of the safety-relevant buildings and extended within the framework of backfitting measures. New buildings were designed according to the increased requirements and the measures against induced vibrations have been improved.

For the newer construction lines, the design against aircraft crash also covered, aside from the reactor building, further buildings with systems serving the control of this hazard (e.g. the emergency feedwater building in newer PWRs). Furthermore, protective measures were taken into account for the vibrations in internals and components induced in the event of an aircraft crash, e.g. by uncoupling the ceilings and inner walls from the outer wall or by a special design.

In addition to the impact load-time diagram as load assumption, the “Safety Requirements for Nuclear Power Plants” require considering the following issues:

- vibrations induced by the impact of an aircraft,
- kerosene fires at the plant site,
- kerosene explosions outside of buildings,
- fire or explosion of kerosene having penetrated into buildings,

- intrusion of combustion products into ventilation systems, and
- protection against the impact of debris

Components and systems containing high activities of radioactive substances (e.g. ion exchangers of the coolant purification system) are to be protected separately against the impacts of an aircraft crash to prevent any release of radioactive materials into the environment.

Protection against blast waves

The requirements for protecting nuclear installations against pressure waves from chemical reactions in case of an accident outside the installation were developed in the 1970s due to the specific situation of sites located on rivers with ship traffic and transport of explosive goods. The protective measures are based on the assumption of a maximum pressure of 0.45 bar at the site and that a certain safety distance is kept to potential blast or release locations (e.g. transport routes, industrial plants) a certain safe distance from potential explosion places or release locations (e.g. transport routes, industrial plants) is complied with. They are regulated in detail in the guideline for the protection of nuclear power plants against pressure waves from chemical reactions by means of the design of nuclear power plants with regard to strength and induced vibrations and by means of the adherence to safety distances.

Regulatory measures

After the applicant had pre-selected a site, a regional planning procedure was initiated which preceded the nuclear licensing procedure. This took into account all impacts of the planned project on the public, on traffic routes, regional development, landscape protection and nature conservation. Besides the site characteristics, the design of the nuclear installation against external hazards was checked in the nuclear licensing procedure (→ Article 7 (2ii)). Furthermore, investigations were carried out as to whether public interests oppose the selection of the site. As part of the nuclear licensing procedure, the respective competent authorities also checked compliance with the requirements regarding water rights, immission control and nature conservation. The construction permits and operating licences of the German nuclear power plants have all been granted before Directive 2011/92/EU of the European Parliament and the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (EIA Directive) entered into force. Assessments of environmental impacts were exclusively performed according to national law.

In case of nuclear licensing procedures within the scope of essential modifications of the installation, the AtG requires to also assess the environmental impacts according to the UVPG.

17 (ii) Evaluation of the likely impacts of the nuclear installation on the environment

With regard to the impacts that an operating nuclear installation has or could have on the environment and on the people living in its vicinity, distinction is to be made between conventional impacts, which would also emanate from other industrial facilities, and radiological impacts both during normal operation of the installation and in case of design basis accidents.

Conventional impacts of the nuclear installation on the environment

Thermal discharge into rivers or water bodies from discharged cooling water during power operation must not exceed the limits specified in the nuclear licensing procedure. Here, the regulations under water law generally set tighter limits than the safety requirements with regard to heating of river water. If, due to extreme weather conditions, it is foreseeable that the permissible temperature rise would be exceeded, the respective nuclear installation must reduce its power according to the provisions laid down in the operating manual (BHB) or it must possibly be shut down.

A separate licensing procedure under water law is required for the utilisation of water and the discharge of cooling water and waste water, which is conducted in coordination with the nuclear licensing procedure.

Furthermore, impacts of the installation or parts thereof on the environment (e.g. air, noise, light) have to be considered according to the Federal Immission Control Act (BImSchG) and the related ordinances. To this end, corresponding licences were included in the nuclear licence when the installation was built (§ 8 AtG). Subsequent modifications of the installation or amendments to the BImSchG require appropriate modification and amendment procedures. This concerns e.g. the auxiliary boiler plant, which is conventionally fuelled in most cases, and transformers > 220 kV that are not surrounded by a building structure. If the changes also have an impact on nuclear safety, the nuclear licensing and supervisory authority also has to be involved, otherwise, it is merely to be informed.

Radiological impacts during normal operation of the nuclear installation and design basis accidents

The dose limits and planning levels for the exposure of the population specified in radiation protection law shall be complied with during specified normal operation of the installations and in the case of design basis accidents. These are dealt with in Article 15.

Implementation of the requirements in the nuclear licensing procedure

The nuclear licensing procedure (→ Article 7) is regulated in the Nuclear Licensing Procedure Ordinance (AtVfV). According to § 15(2) sentence 1 AtVfV, the competent nuclear licensing and supervisory authority can only issue a licence for a nuclear installation if the licensing requirements are fulfilled or if their fulfilment can be ensured by ancillary provisions. The licensing requirements include the requirements regarding the conventional and radiological impacts of the nuclear installation on the environment described in this article. The nuclear licensing and supervisory authority has to verify fulfilment of these requirements as part of the nuclear licensing procedure. It is ensured by provisions of the AtVfV that the nuclear licensing and supervisory authority will carry out this review and will take it into account in its decision. In this context, § 14a of the AtVfV is of special importance.

§ 14a(1) AtVfV obligates the nuclear licensing and supervisory authority in projects requiring an environmental impact assessment – like e.g. the construction or any essential modification of a nuclear installation – to prepare a summarised presentation prior to licensing. It includes the impacts of the project on the environment, i.e. on humans, including human health, animals, plants and biological diversity, soil, water, air, climate, landscape, etc., that are relevant for the decision on the licence application. This presentation is based on the documents submitted by the applicant, various official statements, the results of the authority's own official studies, and comments and objections by third parties.

§ 14a(2) sentence 1 AtVfV stipulates that the nuclear licensing and supervisory authority has to assess the impacts of the project on the environment on the basis of the summarised presentation in line with legal and administrative provisions that are relevant for its decision. According to § 14a(2) sentence 4 AtVfV, the nuclear licensing and supervisory authority has to consider the assessment it has made or the overall assessment in the decision about the application in accordance with the applicable legal provisions.

17 (iii) Re-assessment of the site-specific conditions

Measures for re-assessment

Article 17 (i) describes the design of German nuclear installations against external hazards. The SÜs which are to be performed every ten years (→ Article 14 (i)) also include a re-evaluation of the protective measures against external hazards, taking into account any advancement in the state of knowledge. As a result of these reviews, measures have been taken or planned as far as necessary.

The “Safety Requirements for Nuclear Power Plants” serve as a measure for assessing the protection against internal and external hazards as well as against man-made external hazards (in particular Appendix A of the “Guide Safety Status Analysis”).

Section 2.4 (1) of the “Safety Requirements for Nuclear Power Plants” requires the following: “All equipment that is necessary for shutting the reactor down safely, for maintaining it in shutdown condition, for removing the residual heat or for preventing a release of radioactive materials shall be designed such and be able to be maintained in such a condition that they fulfil their safety-related functions even in the case of internal and external hazards as well as very rare human induced external hazards (see Annex 3).” In this respect, the following hazards have to be considered in particular:

- natural external hazards, as far as to be considered site-specifically, such as earthquake, flooding, extreme meteorological conditions (e.g. high or low temperatures of outside air or cooling water, storm, snowfall, icing, lightning stroke) or biological impacts, and
- man-made external hazards, such as aircraft crash, plant-external blasts, impact of dangerous substances and other man-made hazards (e.g. impact of flotsam, loss of cooling water due to failure of a river barrage downstream, consequences of shipping accidents).

In the nuclear rules and regulations, accidental aircraft crash, blast wave and the impact of hazardous substances are referred to as very rare man-made external hazards or man-made hazard conditions. Man-made hazard conditions are controlled by means of specially protected emergency equipment. For these, less stringent redundancy requirements apply than for the systems for the control of design basis accidents which have to control the single failure and the simultaneous maintenance case in the event of a hazard-induced impact.

Regulatory assessments and activities

The SÜs of the nuclear installations that are to be or have been submitted according to the AtG are reviewed with the support of expert organisations, using the current guidelines of the competent nuclear supervisory authority.

17 (iv) Consultations with neighbouring countries

International agreements and European law

Germany is a contracting party to the “Convention on Environmental Impact Assessment in a Transboundary Context” (Espoo Convention). At the level of the European Union (EU), the provisions of the Espoo Convention are implemented by the EIA Directive. These international and European obligations for cross-border participation have been implemented, in particular, through an amendment of the AtVfV. In particular, the authorities of neighbouring countries will be involved in the nuclear licensing procedure if a project could have significant impacts in another state.

Moreover, there is also another tool for assessing possible impacts of projects on neighbouring countries: In accordance with Article 37 of the Euratom Treaty, the European Commission will be informed of any plan for the discharge of radioactive materials in whatever forms. For this purpose, general information on the site and the essential characteristics of the nuclear installation are submitted, at least six months before the competent authority issues a licence permit for the discharge in question. This serves to establish the possible impacts in other member countries. After a hearing with a group of experts, the Commission comments on the project.

Bilateral agreements with neighbouring countries

In addition to the international instruments described, from a very early stage, Germany took up cross-border information exchange with its neighbouring countries in connection with nuclear safety and radiation protection.

At present, bilateral agreements exist with eight of Germany's nine neighbouring countries (Belgium, the Netherlands, France, Switzerland, Austria, the Czech Republic, Denmark and Poland) on the intergovernmental exchange of information, in particular on nuclear facilities close to the border.

Joint commissions for regular consultation on issues of nuclear safety and radiation protection have been established bilaterally with Belgium, France, the Netherlands, Switzerland, Austria and the Czech Republic. The intergovernmental exchange of information relates in particular to nuclear installations close to the border and concerns above all

- technical or licensing-relevant modifications,
- operating experience, especially with regard to reportable events,
- regulatory development of the “Safety Requirements for Nuclear Power Plants” and, in particular, also with regard to accident management measures for severe accidents, and
- reporting on developments in nuclear energy policy and radiation protection.

Overall, the cross-border cooperation enables the neighbouring countries to assess the impacts nuclear installations in border regions will have on the safety of their own country. The agreements on information exchange and mutual assistance in the case of emergencies with neighbouring and other countries and further agreements with other countries as well as with the International Atomic Energy Agency (IAEA) and the EU are dealt with in Article 16 (2).

Implementation of the “Vienna Declaration on Nuclear Safety”

The SÜs of the nuclear installations described in Article 14 (i), that are to be carried out every ten years, also include a re-evaluation of the impact of the site on the safety of the nuclear installations (→ Article 17 (iii)). In addition, an unscheduled special review of the impact of site conditions on safety was carried out for all nuclear installations as part of the EU stress tests. The review showed i.a.

- that for all sites, there are safety margins to the design requirements for hazards from earthquakes due to the conservative design and the seismic activity at the sites, and
- that the protection concept of all nuclear installations in Germany against flooding beyond the design event (exceedance probability of 10^{-4} per year, contains additional safety margins.

Based on further investigations of the licence holders, the RSK assumes that safety margins also exist with regard to beyond-design-basis weather-induced hazards.

The nuclear licensing and supervisory authorities of the countries confirmed that the reports of the licence holders are in compliance with the EU stress test requirements.

18 Design and construction

ARTICLE 18 DESIGN AND CONSTRUCTION

Each Contracting Party shall take the appropriate steps to ensure that:

i) the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defense in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;

ii) the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;

iii) the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.

18 (i) Implementation of the defence-in-depth concept

Overview

According to § 7(2) of the Atomic Energy Act (AtG), precautions shall be taken to prevent damage resulting from the construction and operation of nuclear installations. For this purpose, the state of the art in science and technology is defined as the benchmark for granting a licence. The "Safety Requirements for Nuclear Power Plants" require the following: "In order to meet the radiological safety objectives, the radioactive materials present in the nuclear power plant shall be multiple confined by technical barriers and/or retention functions, and their radiation shall be sufficiently shielded. The effectiveness of the barriers and retention functions shall be ensured by the fulfilment of fundamental safety functions. A defence-in-depth concept shall be realised that ensures the fulfilment of the fundamental safety functions and the preservation of the barriers and retention functions on several consecutive levels of defence as well as in the case of any internal and external hazards." (Section 2 (1)).

This is concretised by requirements in terms of a concept of the different levels of defence, a concept of multi-level confinement of the radioactive inventory (barrier concept), a concept of main safety functions and a concept of protection against internal and external hazards as well as against very rare man-made external hazards.

Implementation

The main requirements of the "Safety Requirements for Nuclear Power Plants" had already been taken as a basis for the design of the first construction lines. For the planning, implementation and execution of measures and the design, manufacture and operation of equipment at levels of defence 1 to 4, the following principles for the promotion of safety apply:

- well-founded safety margins, depending on the safety significance of the system,
- inherently safe-acting mechanisms,
- use of qualified materials, manufacturing and testing methods,
- maintenance- and test-friendly design of equipment,
- ergonomic design of the workplaces,
- high quality in manufacturing, construction and operation,
- carrying out of in-service inspections,
- monitoring of the state of the installation,

- concept for the detection of operation- and ageing-induced damages, and
- evaluation and safety-related consideration of operating experience.

For safety systems of level of defence 3, the following design principles shall be applied to ensure the necessary reliability:

- redundancy,
- diversity,
- segregation of redundant subsystems,
- physical separation of redundant subsystems,
- safety-oriented system behaviour in case of malfunctions of subsystems or components,
- preference of passive safety features,
- high availability of necessary auxiliary and supply systems, and
- automation (during the first 30 minutes of an accident sequence, manual actions by the shift personnel are not required, but possible).

These principles have been realised plant-specifically in all German nuclear installations, as far as technically feasible and reasonable.

The separation of redundancies is not only realised in the area of engineered systems, but also in the area of instrumentation and control. Due to the physical or spatial separation of safety-relevant components, an influence of neighbouring redundancies, e.g. in case of system-immanent failures (e.g. jet forces), flood, fire or in case of external hazards, are precluded. At the component level, the diversity principle is realised, above all, in those areas where the potential for systematic failures (e.g. common cause failures (CCFs)) is great and highly safety-relevant.

In the following, the levels of defence are described and backfitting measures to strengthen the defence-in-depth concept specified. Other backfitting measures are described in Article 14.

Level of defence 1:
The objective of level of defence 1 is to ensure normal operation (undisturbed, specified normal operation) and to avoid abnormal operation.

Level of defence 2:
The objective of level of defence 2 is the control of operational occurrences and the avoidance of abnormal operation. The level of defence is characterised by the disturbed, specified normal operation.

At the second level of defence, particular importance is attached to the limitation systems that precede the reactor protection system. There are three types of limitation systems that are classified according to task and requirement. In case of anticipated operational occurrences, the limitations shall automatically limit the process variables to defined values in order to increase the availability of the installation (operational limitations) and to maintain initial conditions for the accidents to be considered (limitations of process variables). Furthermore, safety variables are brought back to values at which continuation of specified normal operation is permissible (protective limitations).

The overall objective is to reach a high degree of automation for relief of man from short-term measures and comprehensive preventive measures to counteract the development of anticipated operational occurrences into accidents and a high tolerance against human failures.

Level of defence 3:
The objective of level of defence 3 is the control of design basis accidents and the prevention of multiple failure of engineered safety features safety. For this purpose, highly reliable safety systems and the reactor protection system are used.

Level of defence 4a:
The objective of level of defence 4a is the control of events with postulated failure of the reactor scram system (ATWS).

Level of defence 4b:
The objective of level of defence 4b is the control of events with multiple failure of safety systems to prevent accidents with severe core damage.

Here, preventive measures of accident management (level of defence 4b) are used which are to maintain or restore core cooling and transfer the installation into a safe state.

Level of defence 4c:
Subsection 2.1 (3b) of the "Safety Requirements for Nuclear Power Plants" stipulates that on level of defence 4c "mitigative measures of the internal accident management shall be provided for accidents involving severe fuel assembly damages for the purpose of maintaining – by using all available measures and equipment – the integrity of the containment for as long as possible, excluding or limiting releases of radioactive materials into the environment according to Subsection 2.5 (1), and achieving a long-term controllable plant state."

The mitigative measures of level of defence 4c are provided in order to practically exclude events that could lead to

- any releases of radioactive materials caused by the early failure of the containment or
- any releases of radioactive materials requiring wide-area and long-lasting measures of off-site emergency preparedness,

by using all available measures and equipment, or to limit their radiological consequences to such an extent that off-site emergency preparedness measures will only be required to a limited spatial and temporal extent. For the nuclear installations in operation, the practical exclusion of events with early or large releases is proven by the interaction of plant operation, high reliability of the safety system and a comprehensive accident management.

Section 4.4 "Accidents involving severe fuel assembly damages" of the "Safety Requirements for Nuclear Power Plants" stipulates that for event sequences or plant conditions for which no emergency measures have been planned in advance or for which the implemented emergency measures prove to be ineffective, recommendations for action for the crisis management team shall be provided. In all German nuclear installations, these recommendations for action for the crisis management team are provided in the form of the accident mitigation manual (HMN) as a supplement to the existing emergency manual (NHB). The strategies and procedures contained in these manuals correspond to the international recommendations on SAMGs (Severe Accident Management Guidelines).

Improvements in systems engineering carried out during the review period on the basis of deterministic and probabilistic assessments (2017 – 2019)

The modifications and improvements of recent years resulted mainly from the operational experience feedback due to Information Notices (WLNs) of the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH. It was also possible to implement the results of the robustness analyses for maintaining the vital functions in case of beyond-design-basis impacts and plant states.

Regulatory reviews and monitoring

Design and construction of a nuclear installation according to the national nuclear rules and regulations and the licensing process are described in Article 7. In this context, the internationally accepted design principles, such as redundancy, single failure concept and physical separation are considered. In the licensing procedure it was verified e.g. that the releases of radioactive materials determined for all design basis accidents (events of level of defence 3) under conservative boundary conditions are significantly below the planning values of § 94 StrlSchV.

The procedures applied to backfitting measures or modifications important to safety to the plant are the same as those applied to the construction of a nuclear installation (→ Article 7). Here, however, a graded approach is applied that depends on the safety relevance of the planned measure. The procedures specified by the regulatory authorities for modification or backfitting measures are basically the same for all nuclear installations. A distinction is made between modifications that are subject to a formalised modification procedure and modifications that are not subject to this procedure. The former modifications include safety-relevant modifications to structures, systems and components and to operating procedures. The procurement of spare parts, editorial changes in documents or modifications to non-qualified components, e.g., are not subject to the modification procedure. In order to limit the efforts, modifications are divided into categories. The assignment of a modification to a category is based on the safety significance of the modification. Modifications of the highest category require a licence by the competent nuclear licensing and supervisory authority of the individual *Land*, modifications of the lowest category can be carried out by the licence holders on their own responsibility. The first category comprises e.g. modifications which result in an increasing activity inventory in the installation due to a reactor power increase. The lowest category includes e.g. modifications that cannot affect the safety level of the installation. In addition to technical modifications and modifications of operational specifications, e.g. organisational modifications, are also subject to the modification procedure. Depending on the modification measure, other authorities such as building authorities, trade supervision or environmental protection agencies are also involved in the nuclear licensing procedure.

Expediency and effectiveness of all systems, equipment and measures originally available or backfitted is continuously checked by means of the operating experience gained (→ Articles 14 and 19) and the integrated event analysis including the interaction between man, technology and organisation (→ Articles 19 and 12) also with regard to further optimisation possibilities. Additional regulatory control takes place within the framework of the Safety Review (SÜ) (→ Article 14).

18 (ii) Qualification and proof of incorporated technologies

Legal and regulatory requirements for the use of technologies proven in operation or sufficiently tested

Section 3 “Technical requirements” of the “Safety Requirements for Nuclear Power Plants” requires the use of qualified materials and of equipment that has been proven by operating experience or has been sufficiently tested.

A quality assurance system according to safety standard KTA 1401 “General Requirements Regarding Quality Assurance” ensures that the requirements are fulfilled and maintained. The safety standards of the Nuclear Safety Standards Commission (KTA) contain further extensive requirements regarding qualification and proof of incorporated technologies and the reliability of safety-relevant structures, systems and components. The requirements are classified according to the safety relevance of the system or equipment. Details regarding the technical realisation are specified in the regulations and guidelines. These are, above all, the standards of KTA series 1400 “Quality assurance”, 3200 “Primary and secondary circuits”, 3400 “Containment”, 3500 “Instrumentation and reactor protection”, 3700 “Energy and media supply” and 3900 “Other systems”.

Measures for the introduction of proven technologies

Materials and construction

General requirements apply to the qualification of the materials used according to the conventional and national nuclear rules and regulations. The qualification tests largely follow the practice from engineering experience with industrial installations requiring regulatory supervision and from regulations in terms of construction supervision. In the case of nuclear installations, both type and extent of the required certification are expanded, compared to the conventional requirements, in accordance with the safety relevance of the components.

With respect to the structural design of pipes, vessels and supporting structures, there are requirements with regard to a favourable distribution of stresses and strains and to ease of inspection. As far as specific nuclear influences are expected, e.g. by radiation, this is accounted for in the corresponding requirements regarding materials and qualification certifications.

The influence of identified quality-reducing factors on the safety margins regarding the manufacturing of components was examined and proof has been delivered that the requirements contained in the standards consider sufficient margins.

The detailed requirements for a qualification proof of the manufacturing process used are specified in safety standards. Different standards apply, depending on the materials, product forms, or the scope of application, e.g. pressure retaining boundary, secondary systems, containment and lifting equipment. The qualification proof of the manufacturing process is carried out for each manufacturer individually and is repeated at specified time intervals. An independent authorised expert participates in manufacturing steps that are important with respect to the qualification of the materials, the manufacturing process and components. The results of the tests are documented and the evaluations of the authorised experts are submitted to the nuclear licensing and supervisory authority.

Active components

For the majority of active components and their operating hardware, the manufacturers and licence holders of the nuclear installations make use of series-produced items for which extensive industrial experience is available. This applies in particular to electrical components and the instrumentation and control equipment, such as electric motors, controller drives, switchgears, electronic measuring instruments, data processing equipment and cables. However, components used in mechanical engineering may also be series-produced items. Typical examples are the valves and pumps, as far as they do not belong to the pressure-retaining boundary, but, e.g., those used in cooling water and auxiliary systems as well as for turbines. Such equipment is used in conventional power producing facilities and in the chemical industry. The same applies to the consumable operating media, such as oils, lubricants, fuels, gases and chemicals e.g. for water conditioning.

Type and extent of the qualification proof are specified both in nuclear and in conventional standards in accordance with the individual safety significance. Wherever specific nuclear influences are expected, e.g. by the ambient conditions, the qualification is shown with supplementary, in many cases experimental proofs. This applies, for example, to failure resistance. In those particular cases where no industrial experience is available for individual components, the qualification of the technology involved is verified in extensive series of tests and the results obtained submitted to the nuclear licensing and supervisory authority for review.

Analyses, tests and experimental methods for the qualification of technique applied and new technologies

The suitability and qualification of the technologies applied is proven in various ways. These are

- practical experience with long-term use under comparable operating conditions,
- experimental investigations on the behaviour of the materials and components used under operating and accident condition, or seismic impacts,
- proof on the basis of verified models,
- proof of the long-term behaviour by artificial accelerated ageing,
- reliability data or service life certificates for components of the I&C equipment, and
- critical load analyses.

The feedback of experience from manufacturing and operation are of great significance to the evaluation of qualification proof of the installed techniques and technologies (→ Article 19).

Furthermore, the instrumentation needed for a more exact determination of local loads, e.g. due to thermal stratifications and cyclic stresses, was increased in all nuclear installations. The results from these measurements are used both for optimising operating procedures as well as in ageing assessments for a more reliable determination of the utilisation factor of components.

Annex 5 of the “Safety Requirements for Nuclear Power Plants” defines detailed requirements for safety demonstrations and documentation. Accordingly, the applicability of the analysis tools for safety-relevant proofs shall be validated.

Regulatory reviews and monitoring

The test programmes are submitted to the competent licensing and supervisory authority and reviewed by the authorised experts consulted (§ 20 AtG). Furthermore, the authorised experts participate in tests and trials, some of them also being conducted at the manufacturer’s. With regard to aspects important to safety, the authorised experts consulted carry out own analysis, preferably with independent calculation models.

The authorised expert reviews all aspects to be assessed as to whether additional requirements could be necessary beyond those specified in the applicable standards and guidelines and proposes them to the competent nuclear licensing and supervisory authority. Decisions are taken by the nuclear licensing and supervisory authority.

18 (iii) Design for reliable, stable and easily manageable plant operation

Overview of the regulatory basis for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface

The basic requirements for the design of nuclear installations, requirements as regards simplicity of system design (ergonomics), physical separation of redundant subsystems as well as accessibility for inspections, maintenance and repairs are laid down in the “Safety Requirements for Nuclear Power Plants”.

High reliability of systems and components has already been achieved during design, construction and manufacturing by adherence to the design principles. These include the use of high-quality materials and comprehensive quality assurance. A maintenance concept ensures high reliability and availability of systems and components for the lifetime of the installation. Thus, appropriate design and quality of the systems and equipment of the first level of defence ensures a reliable and undisturbed operation and reduces the probability of occurrence of incidents and accidents.

Section 3 “Technical requirements” of the “Safety Requirements for Nuclear Power Plants” includes requirements for the ergonomic design of the prerequisites for reliable personnel actions. Detailed requirements are defined, among others, in the KTA safety standards. The technical measures as well as provisions in relation to the organisation and implementation of work procedures are stipulated in the safety standards of the KTA series 1200 “General, Administration, Organisation” and 3200 “Primary and Secondary Circuits”.

Personnel qualification

In addition to technical means, human and organisational measures and their interactions are also of high significance for the safety of the nuclear installations. Therefore, the AtG and the other legal regulations and substatutory guidance instruments mentioned provide that for licensing the fulfilment of requirements regarding reliability, the requisite qualification and knowledge of the groups of persons defined therein is equally necessary as the fulfilment of the requirements regarding precautions to prevent damage. These requirements must be seen comprehensively and also extend to the economic reliability and appropriateness of the organisation (→ Article 9).

Integrity concept

The concept of basic safety was developed in the late 1970s. It contains detailed provisions with the objective of preventing catastrophic failure of pressure-retaining components due to manufacturing defects. In the national nuclear rules and regulations, this concept is enshrined in the “Safety Requirements for Nuclear Power Plants” and in the nuclear safety standards of the KTA.

The basic safety of a component is characterised by the following principles:

- high-quality materials, especially with respect to fracture toughness,
- conservative stress limits,
- avoidance of peak stresses by optimisation of the design,
- ensuring application of optimised manufacturing and test technologies,
- knowledge of any possible fault conditions and their evaluation, and
- accounting for the operating medium.

In Germany, the concept of basic safety was enhanced to the integrity concept in order to ensure component integrity during operation of light water reactors. Recent developments incorporate ageing processes and their control in the overall concept, which puts all aspects of integrity proof into interrelations (→ Appendix 3). The main process elements of the proof of integrity have been incorporated in safety standard KTA 3201.4 “Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 4: In-service Inspections and Operational Monitoring” in the form of a process diagram.

The proof of integrity is of high relevance for piping systems with break preclusion. These are to be designed such that during in-service inspections, indication changes or service-induced cracks must not occur. Until now, the integrity concept has been proven in practice and presents an important contribution in terms of damage precaution. Safety standard KTA 3206 “Verification Analysis for Rupture Preclusion for Pressure Retaining Components in Nuclear Power Plants” represents the technical basis for this concept.

Measures introduced by the licence holders and technical improvements

There were no major changes during the review period.

Monitoring and control by the nuclear licensing and supervisory authorities

Prior to performance, the licence holder of a nuclear installation has to submit modifications relevant to safety of the installation or its operation to the nuclear licensing and supervisory authority for licensing or approval within the supervisory procedure (→ Article 18 (i)). The regulatory review is usually performed with the involvement of authorised experts. It is checked whether the requirements of the national nuclear rules and regulations are fulfilled. The review also includes the consideration of findings and knowledge gained from the operating experience as well as of human factors and the man-machine interface.

Implementation of the "Vienna Declaration on Nuclear Safety"

As described in Article 6, point 1 of the "Vienna Declaration on Nuclear Safety" cannot be implemented in Germany since, according to § 7(1) sentence 2 AtG, no further licences will be issued for the construction and operation of installations for the fission of nuclear fuel for the commercial generation of electricity.

In Germany, the exclusion of events with early or large releases is already required for the nuclear installations in operation by the measures described in this article under the heading "Level of defence 4" and is also to be proven by the licence holders of the nuclear installations. The proof can be provided by fulfilling the requirements for the operation of the installation, the high reliability of the safety system and a comprehensive accident management. In this context, comprehensive backfitting measures have already been conducted at the German nuclear installations in the preventive area after the Chernobyl accident (→ Tables 6-2 and 6-3).

19 Operation

ARTICLE 19 OPERATION

Each Contracting Party shall take the appropriate steps to ensure that:

i) the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;

ii) operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;

iii) operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;

iv) procedures are established for responding to anticipated operational occurrences and to accidents;

v) necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;

vi) incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;

vii) programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;

viii) the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.

19 (i) Initial authorisation

In Germany, the granting of a licence is regulated, in particular, in § 7 of the Atomic Energy Act (AtG) and in the Nuclear Licensing Procedure Ordinance (AtVfV). The licences for construction and operation of the eight nuclear installations in Germany still authorised for power operation have been issued in several partial licences. For this purpose, each installation had to submit a safety report and demonstrate compliance with the design and safety requirements of the then applicable national nuclear rules and regulations.

A detailed description of the nuclear licensing processes in Germany is contained in Article 7 (2 ii).

Safety analysis

The operating licences of the nuclear installations are based on the results of a safety analysis and its detailed review by the competent nuclear licensing and supervisory authority of the respective *Land*. Details on how the safety analysis is carried out are provided in Article 14 (i).

Commissioning programme

In Germany, the commissioning programmes were generally carried out in four phases:

- Commissioning of the systems:
  During commissioning of the systems, all necessary functional and operational tests were performed to ensure that the individual components and systems were available in proper functioning order.
- Hot functional run, Phase 1:
  In the hot functional run, Phase 1, the reactor coolant system was operated for the first time together with the reactor auxiliary and other systems in order to ensure proper functioning of the installation as a whole. In this phase, functionality was tested without fuel loading of the reactor.

- Hot functional run, Phase 2:
  Hot functional run, Phase 2, was performed to verify the functionality and the safety of the installation as a whole after initial fuel loading of the reactor before starting nuclear operation.
- Tests at zero- and partial-load levels:
  After reaching criticality for the first time, comprehensive tests at zero- and partial-load levels were carried out at each appropriate power stage.

Accompanying control during construction

In parallel to the construction and commissioning of the reactor, manufacturing and installation of safety-relevant systems and components were controlled. For this purpose, compliance of the systems and components with the then existing requirements was verified by the licence holder as well as by the authorised experts consulted by the nuclear licensing and supervisory authority.

Regulatory supervision

The scope of supervision under nuclear law by the competent licensing and supervisory authorities during construction and commissioning of nuclear installations was based on the then applicable safety and design requirements of the national nuclear rules and regulations.

19 (ii) Operational limits and conditions of safe operation

Legal and regulatory requirements

According to the requirements of the AtVfV, all safety-relevant data concerning the nuclear installation and its operation were to be submitted with the application documents for an operating licence.

The requirements relating to the operating manual (BHB) and the safety specifications are laid down in safety standard KTA 1201 “Requirements for the Operating Manual”. More detailed requirements for safety specifications are included in the guidelines concerning the requirements for safety specifications for nuclear power plants.

All operational and safety-related instructions, operational limits and conditions for the safe operation of an installation are contained in the BHB as safety specifications, including all operational and safety-related regulations and the safety specifications required for safe operation, the control of anticipated operational occurrences and accidents.

The safety specifications of each nuclear installation are determined installation-specifically, defining the operational limits for various plant states and describing what influence it may have on the safe operation of the installation if these limits are exceeded or if the values fall below the specified limits.

The safety specifications are part of the nuclear licensing process and must be submitted by the applicant as a condition for the granting of an operating licence. They are a binding and updated documentation of the permissible framework for the operating mode of an installation in terms of safety.

Specification of limits and conditions

The BHB contains all operational and safety-related instructions, limits and conditions that are required for normal operation of the installation as specified and for the control of anticipated operational occurrences and accidents as well as operating regulations. These apply to all staff working in the nuclear installation.

The safety specifications are included in the BHB and identified as such.

In case of deviations from limits or conditions of the specified range, the measures to be taken are laid down in the BHB. Irrespective of how fast normal operating conditions can be restored, the result is documented and, if the respective criteria are met, is made part of the internal experience feedback as an alarm notice (→ Article 19 (vi)).

Reviews and revision of limits and conditions

During operation of a nuclear installation, modifications to the safety specifications may become necessary, e.g. due to findings from operating experience or other new findings. In this case, these will be reviewed and adapted. Review and adaptation can be done either at the initiative of the licence holder of the nuclear installation or by order of the nuclear licensing and supervisory authority.

In case of modifications to the safety specifications, the shift personnel concerned will be directly informed through meetings or notices. For the maintenance of technical qualification (→ Article 11 (2)), the simulator training courses prescribed for it are also used to specifically practice new procedures where required.

Regulatory supervision

Modifications to safety specifications as part of the BHB are subject to approval by the competent nuclear licensing and supervisory authority. Should the nuclear licensing and supervisory authorities have indications that modifications to the safety specifications could be required it may initiate reviews and enforce necessary modifications.

The competent nuclear supervisory authorities of the *Länder* monitor compliance with the safety specifications. For this purpose, records of the nuclear installations and reports of the respective licence holders are controlled. This is done on the basis of the regulations specified in the individual nuclear licences.

19 (iii) Procedures for operation, maintenance, inspection and testing

Procedures for operation

In addition to technical prerequisites, licensing of a nuclear installation is also based on personnel and organisational prerequisites (→ Article 9). The approved procedures for operation, including maintenance and testing, but also for the management of anticipated operational occurrences and accidents described in Article 19 (iv) determine the organisational and operational structure of the nuclear installations. This structure is laid down in detail in the BHB of the respective nuclear installation.

Safe operation is the responsibility of the manager of the installation or, in the event of absence, one of the deputies. Quality assurance and radiation protection are separate from the divisions responsible for operation and maintenance and are organised independently.

Further procedures are laid down in the BHB, the emergency manual (NHB) and the testing manual. The safety requirements are contained in the following KTA safety standards:

- safety standard KTA 1201 “Requirements for the Operating Manual”,
- safety standard KTA 1202 “Requirements for the Testing Manual”,
- safety standard KTA 1203 “Requirements for the Emergency Manual”.

Operating Manual

The organisational and operational structure for normal operation of an installation is described in detail and defined in the BHB. In the operative part, it also includes measures for the management of anticipated operational occurrences and accidents. The BHB is kept up to date through a revision service and is subject to the nuclear licensing and supervisory process. In each control room, the current and applicable BHB must be easily accessible to the staff of the control room at any time. In addition, at least one current copy is to be kept available in the remote shutdown station.

The BHB consists of the following parts:

1. **Operating regulations:**
   Organisational structure with the right to give instructions, tasks, responsibilities, subordinations, control room and shift regulation, maintenance regulation, radiation protection regulation, guard and access regulation, alarm regulation, fire protection regulation and first aid regulation
2. **Operation of the entire installation:**
   Prerequisites and conditions for all operating phases, limits important to safety, testing schedule, criteria for reportable events, instructions for normal and abnormal operation
3. **Design basis accidents:**
   Symptom-based (protection-goal-based) and event-based accident management during power or shutdown operation, supplemented by an incident decision guide and transition to the NHB if the protection goals are not met and the identification criteria for an emergency are met.
4. **Systems operation:**
   Instructions for operational processes of all systems under specified initial conditions or operating conditions
5. **Alarms:**
   Alarm signals from failures/malfunctions and hazardous conditions and the corresponding system-related actions initiated automatically or to be triggered manually
6. **Annexes:**
   Lists of documents from the licence of the installation. List of documents and supplementary documents that are not part of Parts 1 to 5 (e.g. chemistry handbook)

Emergency Manual (NHB)

The plant-specific NHB includes organisational regulations and measures for design extension conditions. It contains the descriptions of organisation, responsibilities and tasks, instructions, documents and aids for coping with such an event sequence. This is to identify and control design extension event sequences at an early stage and to mitigate their potential impacts inside and outside of the installation as far as possible. These are planned measures of accident management and situational measures in the preventive and mitigative area. The transitions from the BHB to the NHB and back again to the BHB are defined and described. The NHB is kept up to date through a revision service and is subject to the nuclear licensing and supervisory process. In each control room, the current and applicable NHB must be easily accessible to the staff of the control room at any time. In addition, at least one current copy each is to be kept available at the remote shutdown station and at the work locations of the crisis management team.

The structure of the NHB is symptom-based. If necessary, event-based measures may be added. The chapters relating to the emergency measures are preferably structured according to the main safety functions and protection goals.

The description of the emergency measures includes the objective of the measure, criteria for the selection of an emergency measure, possible cases of emergency, requirements in terms of systems engineering, staffing needs, task location, auxiliary equipment and time needed, grace times, expected effectiveness, description of the measure and effectiveness control.

Maintenance and modifications

Maintenance consists of measures for maintaining and restoring the specified condition of the installation. Furthermore, the actual state (including in-service inspections) is determined and evaluated. For this purpose, the aspects of quality assurance, safety of the installation, radiation protection and personal protection are also taken into account.

One part of maintenance is the preventive maintenance through inspections and servicing. Another part is maintenance through repairs. The work steps from planning of the measure and its implementation up to the restoration of operational readiness and documentation are specified.

Since the construction of the nuclear installations (1969 - 1989), the test and maintenance concepts have been further developed based on new findings from operating experience and results of safety research using deterministic and probabilistic methods.

The requirements for maintenance and modifications are defined in the guideline on maintenance and are supplemented by Chapter 5 of safety standard KTA 1402 “Integrated Management Systems for the Safe Operation of Nuclear Power Plants”.

Testing Manual

The testing manual regulates the frequency and proceeding of the in-service inspections on safety-relevant systems and their components to be conducted by the licence holder of a nuclear installation. It includes general instructions, the testing schedule and corresponding testing instructions for in-service inspections. The testing manual is kept up to date through a revision service and is subject to the nuclear supervisory process.

Furthermore, the testing manual includes descriptions of the proceeding regarding the appointment of external experts, the organisation of performance and evaluation of tests as well as the rules of conduct regarding compliance with testing instructions, tolerance ranges of the testing intervals, and procedures in case of modifications to the testing manual.

The testing schedule contains a list of all in-service inspections important to safety. It covers the test object, the type of test, the scope of the test, the clear designation of the testing instruction, the test interval or the cause of the test as well as the plant condition under which the test is performed.

Regulatory supervision

The competent nuclear licensing and supervisory authority checks within the framework of inspections in the nuclear installations whether the regulations on the organisational structure specified in the BHB are also adhered to in practice. For this purpose, on-site inspections, controls at the control room and controls of organisational processes are conducted. Here, e.g., keeping of the shift log, performance of prescribed walk-throughs or the handling of alarms is checked. In the area of radiation protection, it is checked, e.g., whether dose limits are complied with.

An obligation to review maintenance strategies and measures by the competent nuclear licensing and supervisory authority derives from the “Safety Requirements for Nuclear Power Plants” and the subordinate nuclear rules and regulations (e.g. KTA safety standards, DIN, etc.) whose permanent fulfilment and compliance is subject to review. This is partly laid down in the nuclear licensing documents.

19 (iv) Procedures for responding to operational occurrences and accidents

Legal and regulatory requirements

§ 7(2)3 AtG stipulates that precautions have to be taken as are necessary in the light of the state of the art in science and technology to prevent damage resulting from the construction and operation of an installation. Radiological requirements for operation, design basis accidents and emergencies are contained in § 99 to 104, 106 to 110, 112, 150 to 152 StrlSchV and the Nuclear Safety Officer and Reporting Ordinance (AtSMV). The substatutory "Safety Requirements for Nuclear Power Plants" contain further safety requirements.

Postulated events: anticipated operational occurrences, design basis accidents and emergencies

In Germany, the following event types are considered in addition to normal operation: anticipated operational occurrences, design basis accidents and emergencies. After the occurrence of an event, the shift personnel controls fulfilment of the main safety functions. These are:

- control of reactivity (subcriticality),
- fuel cooling (in the reactor pressure vessel (RPV) and in the spent fuel pool), and
- confinement of the radioactive material (maintenance of barrier integrity).

In case of longer lasting event sequences and independently of the approach for taking corrective measures, the main safety functions are repeatedly checked and the approach chosen adjusted if appropriate.

Specific parameters of the installation are assigned to each protection goal. Should compliance with any of the protection goals be jeopardised or violated, symptom-based procedures are used to bring back the parameters into the normal range. This approach is based on observable plant states (symptoms) and does not require the identification of the actual event.

For the control of design basis accidents, symptom-based or event-based procedures are available to the shift personnel. By means of the so-called incident decision guide it will be decided which measures are to be taken for the management of design basis accidents.

If an accident or failure (e.g. loss-of-coolant accident, failure of heat removal without loss of coolant, etc.) can be clearly identified and if compliance with the protection goals is not jeopardised or violated, event-based procedures are applied. By means of detailed step-by-step programmes, the installation is brought into a long-term safe condition.

The event-based procedures include the following information:

- criteria for identifying the plant state or the event (e.g. accident decision tree),
- naming of the safety-relevant automatic measures,
- naming of the essential measures required for controlling the accident and to be initiated manually by the shift team, and
- details about how to check the effectiveness of the measures with indication of the installation parameters which have to be monitored in particular for staying within permissible limits.

In parallel, it is checked regularly whether the protection goal criteria are still met. Should it be detected that one of the criteria is violated, the event-based procedure is to be discontinued and the symptom-based procedure to be applied.

In case of design extension conditions (emergencies, very rare man-made external hazards), emergency operating procedures and accident management measures are carried out as specified in the NHB.

In addition to the main control room, each German nuclear installation has a remote shutdown station for specific design extension conditions which is protected against external hazards. The issue of accessibility of the remote shutdown station in case of heavily damaged infrastructure (design extension conditions) has already been implemented before the Fukushima accident and the German National Action Plan adopted in response to it.

For all German nuclear installations, it is provided that an emergency organisation and a crisis management team support the measures taken during emergencies organisationally. The crisis management team of the installation concerned is assisted by a crisis management team of the manufacturer of the installation in technical issues. Furthermore, there is the Kerntechnische Hilfsdienst GmbH (KHG), jointly installed by the licence holders of the nuclear installations to cope with emergencies and eliminate possible consequences (→ Article 16).

In addition to the existing NHB, an Accident Mitigation Manual (HMN) has been introduced plant-specifically at all German nuclear installations for their crisis management teams as part of the National Action Plan after the Fukushima accident[28]. The procedures and strategies contained in these manuals comply with the international recommendations on Severe Accident Management Guidelines (SAMGs).

Regulatory review

An essential tool of nuclear supervision of the nuclear installations is the handling of events. Reporting of events by the licence holders to the nuclear licensing and supervisory authorities is regulated in the AtSMV. Accordingly, the licence holders of nuclear installations are required to report design extension conditions, design basis accidents and other events which are important in terms of nuclear safety to the nuclear licensing and supervisory authority. An event in a nuclear installation is reportable if it meets the criteria specified in Appendix 1 of the AtSMV (→ Article 19 (vi)).

According to the AtSMV (→ Article 19 (vi)), research reactors with a capacity of more than 50 kW thermal power are, like power reactors, subject to the obligation to report in case of reportable events. With the amendment of the AtSMV in 2010, separate reporting criteria were specified for research reactors in Annex 3 of the AtSMV.

19 (v) Engineering and technical support

Internal technical support

In accordance with the organisational structure, as implemented at most of the nuclear installations, the production and operation division which is directly responsible for plant operation is supported in its activities by organisational units, e.g. for engineering, maintenance and surveillance. These organisational units, whose integration into the organisational structure may differ from installation to installation, have well-defined tasks and the necessary technical expertise for their fulfilment:

- **Engineering:**
  Maintenance and optimisation of the functionality and operational safety of the mechanical, electrical and I&C components and systems. This also includes the planning and surveillance of modification measures.

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[28] Finalised action plan for the implementation of measures following the reactor accident in Fukushima, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), December 2017, https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/aktionsplan_fukushima_bf.pdf

- **Maintenance:**
  Planning, control, performance and surveillance of maintenance measures, technical modifications and backfitting measures.
- **Surveillance:**
  Working out solutions for all technical issues that concern the nuclear installation or its operation in physics, chemistry, radiation protection, environmental protection, fire protection and physical protection.

Apart from this, the licence holders have established own departments for dealing with general issues, in some cases also at the company's headquarters, in which staff from different disciplines work on generic projects.

External technical support

In case of planned modification measures, the licence holders of the nuclear installations often work together with external partners. If further analyses are required for proofs of safety, the licence holders may use the services of third parties.

Regulatory supervision

The supervisory measures of the *Land* authorities concern, besides controlling quality assurance and documentation, extensive on-site inspections to comprehend how measures important to safety are implemented. The responsibility of the licence holders for the safety of their nuclear installations remains unaffected by this.

For the performance of on-site inspections in the nuclear installations and the clarification and assessment of technical issues, independent expert organisations are consulted (§ 20 AtG). These must have the necessary professional skills and staff capacities. Due to a high inspection frequency, the nuclear licensing and supervisory authorities and their experts obtain highly detailed knowledge about the status of the nuclear installations under supervision.

In addition, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) deals with generic and internationally safety-relevant issues (projects). These projects are financed from the federal budget.

19 (vi) Reporting of events important to safety

Legal and regulatory requirements

According to the AtSMV, the licence holders of nuclear installations are required to report and evaluate events occurring in the nuclear installations (design extension conditions, design basis accidents and other events which are important in terms of nuclear safety).

An obligation of the licence holders to report safety-relevant events to the competent nuclear licensing and supervisory authority of the *Land* was already laid down in the original version of the AtG of 1959. The AtSMV includes reporting criteria for the categorisation of reportable events. Based on these reporting criteria, the licence holders of nuclear installations have to report all safety-relevant events to the competent nuclear licensing and supervisory authority of the *Land* within specified time limits (depending on the reporting categories). The reporting criteria consist of a radiological part, which applies to all installations, and of technical parts, which differ from each other according to the various types of nuclear facilities. For the reporting criteria of the AtSMV, separate explanations are in place. The aim of the explanatory notes on the reporting criteria is – in addition to the necessary specification and description of the radiological and plant-specific reporting criteria and the associated precise definition of the reporting threshold – taking into account the experience of the nuclear licensing and supervisory authorities in the enforcement of the AtSMV and ensuring a uniform enforcement of the AtSMV by the competent nuclear regulatory authorities of the *Länder*. Therefore, the explanatory notes are continuously improved and adapted.

A reportable event is to be notified to the nuclear licensing and supervisory authority of the respective *Land* in writing by means of an official reporting form, including a description of the actual event, its causes and effects as well as the remedial measures taken and the measures provided to prevent recurrence. The nuclear licensing and supervisory authority of the *Land* in turn reports the event to the Incident Registration Centre at the Federal Office for the Safety of Nuclear Waste Management (BfE) as well as to the BMU and the expert organisation Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH. The reportable events are evaluated by the licence holders, authorities, authorised experts and – in so far as necessary – also by the manufacturers.

The BfE informs all nuclear licensing and supervisory authorities of the *Länder*, the authorised experts involved, the manufacturers and the licence holders of the nuclear installations in quarterly reports and the public in monthly and annual reports about the reportable events in nuclear installations according to the AtSMV. The database of the reportable events at the BfE is accessible to the nuclear licensing and supervisory authorities of the *Länder*, the BMU and GRS.

The licence holders of the nuclear installations and the nuclear supervisory authorities inform the public in an appropriate manner about all reportable events in their nuclear installations or those they supervise. Own staff are informed about reportable events by internal communication.

Reporting categories

Reportable events are assigned to one or several reporting categories by means of the reporting criteria based on an initial engineering assessment of the cause of the event. These are as follows:

- **Category S**
  Immediate report – reporting deadline: without delay
  Events must be notified to the nuclear licensing and supervisory authority of the *Land* immediately, so that it can initiate investigations or measures within a very short time period if necessary. This also includes events that indicate acute safety deficiencies.
- **Category E**
  Quick report – reporting deadline: within 24 hours
  These events do not demand any immediate action by the licensing and supervisory authority. For safety reasons, however, the cause is to be identified quickly and, if required, corrective actions are to be taken within a reasonable time period. These are, in general, events that may have a potential – but no direct – significance in terms of safety.
- **Category N**
  Normal report – reporting deadline: within five working days by means of a reporting form
  Events with low safety significance. They are evaluated in order to identify potential weak points at an early stage before any larger disturbances.
- **Category V**
  Prior to commissioning, reporting deadline: within ten working days by means of a reporting form
  Events that occur prior to commissioning of the installation and about which the nuclear licensing and supervisory authority has to be informed with respect to the future safe operation of the installation.

Event statistics

Table 19-1 lists the reportable events having occurred over the last ten years, also indicating the German reporting categories and the INES levels.

Table 19-1 Number of reportable events per year from nuclear installations for electricity generation according to reporting categories

Year	Number	Reporting categories			INES levels		
		S	E	N	0	1	2
2018	76	0	0	76	76	0	0
2017	54	0	2	52	54	0	0
2016	70	1	0	69	69	1	0
2015	60	0	2	58	60	0	0
2014	67	0	0	67	67	0	0
2013	78	0	1	77	77	1	0
2012	79	0	0	79	79	0	0
2011	103	0	0	103	103	0	0
2010	81	0	4	77	80	1	0
2009	104	0	2	102	104	0	0

Figures 19-1 and 19-2 show these events according to the type of occurrence (spontaneously or detection during inspections and maintenance), the operating condition at the time of detection of the event and the impact on operation. Figure 19-3 shows the development of the average number of reactor scrams over the last ten years, also indicating their essential causes.

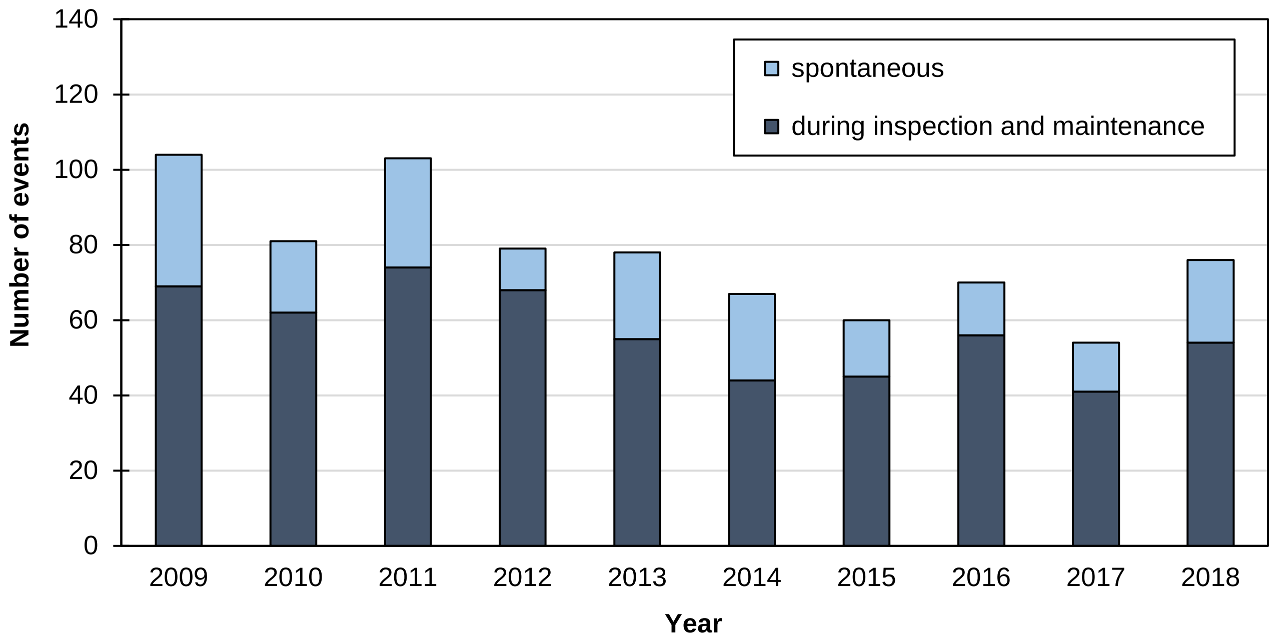

Figure 19-1 Reportable events from nuclear installations for electricity generation according to the type of occurrence

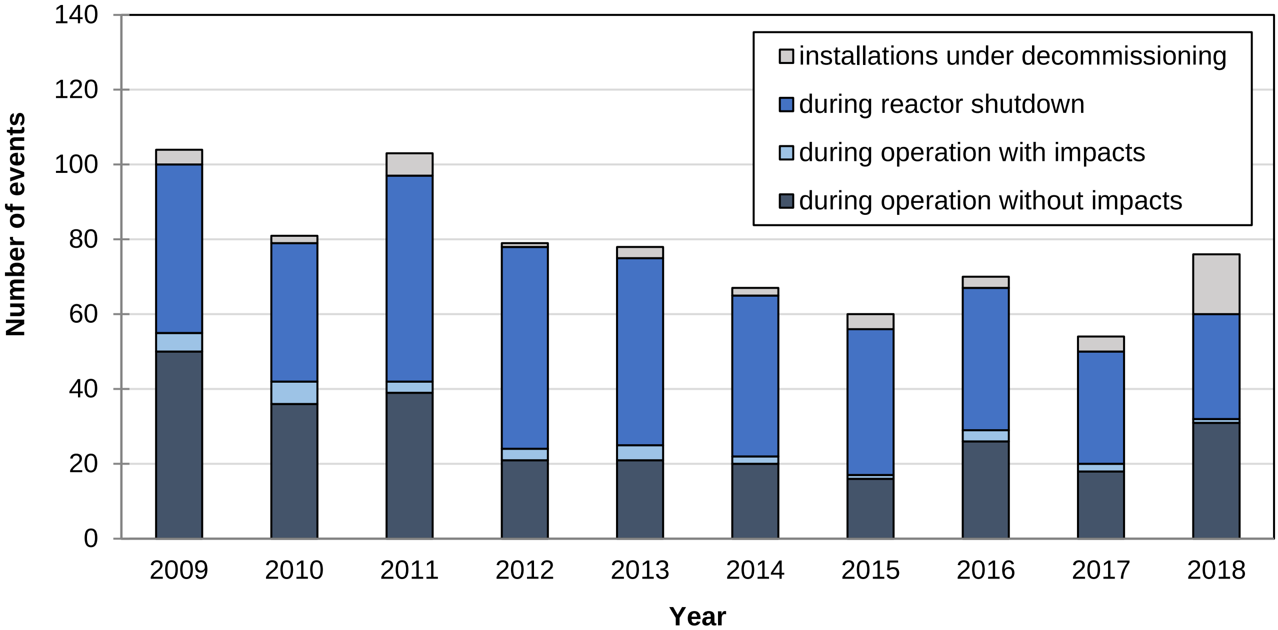

Figure 19-2 **Number of reportable events from nuclear installations for electricity generation according to mode of and impacts on operation (power operation, start-up and shutdown operation**

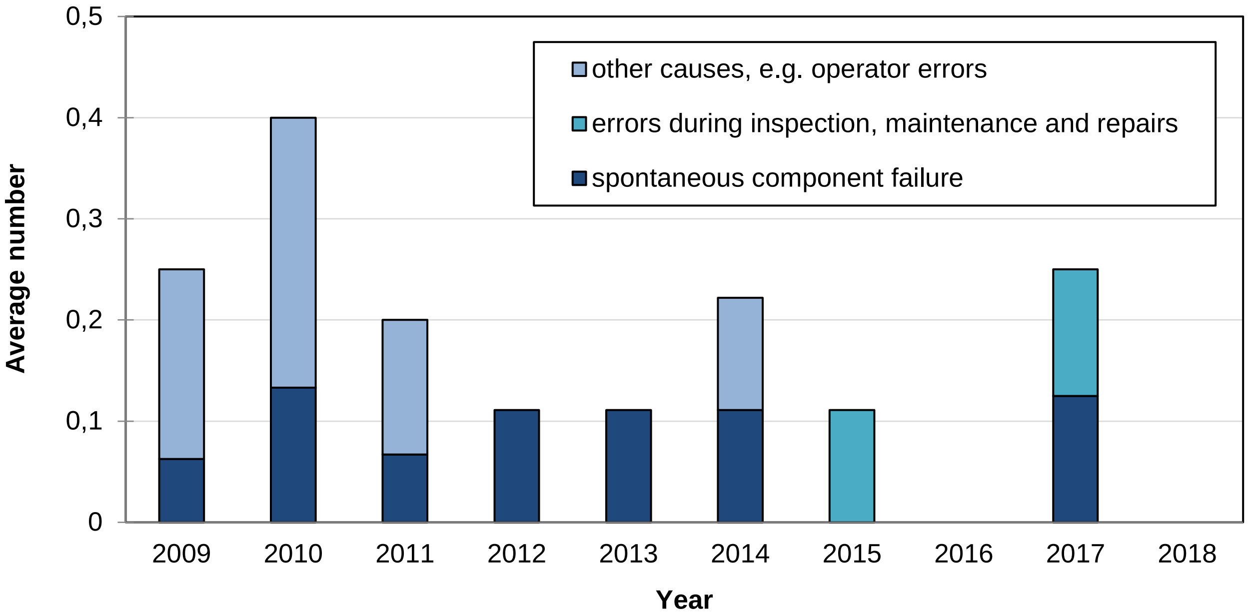

Figure 19-3 **Average number of unplanned reactor scrams per installation and year**

INES classification

Each reportable event is classified by the licence holder of a nuclear installation according to the seven levels of the International Nuclear and Radiological Event Scale (INES) of the International Atomic Energy Agency (IAEA). The INES classification of an event is included in the respective report on the event (reporting form) and is notified together with the report according to the AtSMV, which is the responsibility of the plant manager. As stipulated in the AtSMV, the nuclear safety officer has to check the report for correctness and completeness. Thus, the separation of functions reached by it also applies to the INES classification.

The INES classification is reviewed by the IAEA INES officer officially appointed by the BMU.

Regulatory supervision

If the nuclear licensing and supervisory authority becomes aware of an issue which fulfils the reporting criteria according to the AtSMV or which might fulfil the reporting criteria, this issue is reviewed and assessed at the nuclear licensing supervisory authority, usually with the participation of authorised experts according to § 20 AtG. If necessary, the nuclear licensing and supervisory authority specifies further remedial measures and the precautions to be taken.

19 (vii) Exchange of operating experience

The AtSMV provides the essential basis for the evaluation of operating experience. It stipulates, among others, that the nuclear safety officer shall participate in the evaluations

- of reportable events (→ Article 19 (vi)),
- of other operational occurrences in the own installation,
- of information on reportable events in other nuclear installations in terms of their significance for the own installation, and
- in the exchange of experience concerning safety-relevant operating experience with the nuclear safety officers of other nuclear installations.

Evaluation of operating experience by the licence holders

In Germany, reportable events and events below the reporting threshold of the AtSMV, e.g. failure alarms during maintenance activities, are systematically recorded and evaluated by the licence holders of nuclear installations and measures defined for correction as well as for the prevention of recurrence of similar events. This process is represented in the safety management system of the licence holder (corresponding specifications can be found in safety standard KTA 1402 “Integrated Management Systems for the Safe Operation of Nuclear Power Plants”). If required, a so-called integrated event analysis is performed. For this purpose, the contributing factors from the areas of man-technology-organisation and their interactions are taken into account. To carry out the analysis, in 2014, the Reactor Safety Commission (RSK) has developed a guideline for the performance of integrated event analyses, which has been applied by the German licence holders of nuclear installations after consultation with the VGB since 2015.

With the so-called Central Incident Reporting and Evaluation Office of VGB (VGB-ZMA), the licence holders have an own database for the exchange of generic information. The VGB-ZMA incorporates all German nuclear installations as well as the nuclear installations of the manufacturer KWU (today: Framatome GmbH) abroad. These are the nuclear installations Borssele (Netherlands), Gösgen (Switzerland), Trillo (Spain) and Angra-2 (Brazil). The reportable events are entered into this database by the individual nuclear installations in a timely manner. In addition to the reportable events, it also includes such occurrences which are below the reporting threshold but are of interest to other nuclear installations.

Another function of the VGB-ZMA is being a connecting point to the international reporting system of the World Association of Nuclear Operators (WANO). In this context, WANO reports are reviewed for their safety significance with regard to German nuclear installations. A summary of selected reports is forwarded to the licence holders of the nuclear installations in German on a monthly basis and checked for applicability to their own nuclear installations.

Furthermore, there is a connection to the operating experience evaluation centre of Framatome GmbH. The manufacturer has access to selected events on the VGB-ZMA as well as to information notices (WLNs) and reports of the International Reporting System for Operating Experience (IRS). The applicability and relevance to German nuclear installations is checked and the results for the plant components supplied by the Framatome GmbH communicated.

The plant managers and other specialists are organised in the VGB working groups and committees and exchange more experiences at this level.

National and international evaluation of operating experience on behalf of the BMU

The national Incident Registration Centre is organised at the BfE. The BfE carries out an evaluation of the events reported from the German nuclear installations, including the classification of the events according to the AtSMV, lists all information in a database and reports to the BMU in monthly reports. The database of reportable events is accessible to the nuclear licensing and supervisory authorities of the *Länder*, the BMU and GRS. The current reportable events are discussed in the committees of the RSK on the basis of the monthly reports of the BfE.

On behalf of the BMU, the expert organisation GRS evaluates the national and international operating experience on a holistic basis, partly involving further independent experts (Öko-Institut e.V. and Physikerbüro Bremen). In particular, the international events reported within the IRS of the IAEA and in the Working Group on Operating Experience (WGOE) of the Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) are systematically evaluated with regard to their applicability to German nuclear installations.

In addition, GRS prepares statements at short notice on behalf of the BMU also in the case of special events at foreign nuclear installations.

If the analysis of the events with safety significance reported by German or foreign nuclear installations reveals an applicability to German nuclear installations, GRS prepares WLNs on behalf of the BMU. These are released by the BMU and transmitted by GRS to the nuclear licensing and supervisory authorities of all *Länder* with nuclear installations, the expert organisations, the licence holders of the nuclear installations, the manufacturers and other specialised institutions.

Information notice (WLN)

A WLN includes the following:

- description of the event,
- a root cause analysis,
- assessment of the safety significance,
- measures taken or planned by the licence holder, and
- recommendations on investigations and, where appropriate, corrective measures to be taken at other nuclear installations as an essential element of a WLN.

Upon receipt of a WLN, each licence holder of a nuclear installation then prepares a statement for the competent nuclear licensing and supervisory authority of the *Land*. The focus of this statement is mainly on the implementation of the recommendations of the respective WLN. The plant-specific results of this information feedback are then reported to the BMU by the respective nuclear licensing and supervisory authority of the *Land*, including information about the implementation of the recommendations made. The information feedback is evaluated by GRS and made available to all recipients of the WLNs.

The procedures for recording, processing, evaluating and passing on safety-relevant operating experience from German and foreign nuclear installations have proved themselves over the years. The process is anchored in Supervision Manual of the Federation and *Länder* and is regularly reviewed and further developed. This is to ensure that new sources of knowledge can be identified and included in the feedback of experience.

Moreover, GRS also performs precursor analyses[29] for reportable events in German nuclear installations and participates in international data exchange projects of the OECD/NEA.

Exchange of experience

The licence holders of the nuclear installations as well as the nuclear licensing and supervisory authorities and their expert organisations have various working groups in which operational experience gained and the conclusions drawn are regularly discussed with respect to safety and the general applicability of plant-specific evaluations. Moreover, the reports of the licence holders on plant operation and experience evaluation as well as the WLNs and evaluations of GRS on events in Germany and abroad are also discussed regularly by the RSK.

Experience feedback has shown in particular cases that the suitability of certain technical equipment was to be regarded as insufficient for long-term operation or that there were justified doubts for it. As a part of the safety culture in the Federal Republic of Germany it has proven effective in such cases that all parties involved look for technical solutions in consensus that go beyond what is necessary in terms of safety but would also bring about long-term improvements. Examples of such cases are:

- replacement of pipes in the main steam and feedwater systems of boiling water reactors (BWRs) both inside and outside of the containment,
- backfitting of diverse pilot valves in the overpressure protection system of BWRs,
- conversion of all PWRs to high-AVT (all volatile treatment) of the secondary-side water chemistry,
- fabrication of weld seams for better testability with ultrasonic procedures by machining the weld surfaces, and
- rewelding of seams of components and pipes in PWRs und BWRs.

International databases

Special occurrences at German nuclear installations which are also of interest for the safety of nuclear installations in other countries are reported to the IAEA by GRS in coordination with the BMU, the competent nuclear licensing and supervisory authority of the *Land* and the licence holder of the nuclear installation. Events classified as INES Level 2 and above are reported to IAEA-NEWS in the short term (within 24 hours as specified). Reports with INES classification below Level 2 are forwarded if the events are of public, international interest. Since the introduction of INES, Germany has reported four events in nuclear installations classified as INES Level 2. GRS immediately informs the BMU about events in foreign nuclear installations classified as INES Level 2 or higher and prepares a statement. After approval of the statement, it is sent by the BMU to the *Länder* with nuclear installations. In addition, the BMU informs the *Länder* about events classified as INES Level 2 in foreign nuclear installations in the Working Group Supervision of NPP Operation of the *Länder* Committee for Nuclear Energy (LAA).

[29] Precursors are events in nuclear power plants which, by impairing the function of safety-relevant equipment, by an operational occurrence or by an accident, temporarily significantly increase the probability of damage to the reactor core. Precursor analyses calculate this probability and thus provide a measure of the safety significance of the events.

Regulatory supervision

The procedures of the nuclear licensing and supervisory authorities for recording, processing, evaluating and forwarding of safety-relevant operating experience from German nuclear installations have proven to be effective. However, experience also shows that regular review and enhancement of the procedures are important to ensure that, in the long run, new sources of knowledge are considered in the experience feedback and knowledge gaps identified can be closed.

The independent review by different parties involved is to ensure the high quality of the safety assessment.

Regulatory programmes for the exchange of experience

An intensive exchange of operating experience takes place with Germany's neighbouring countries with nuclear installations (Belgium, France, the Netherlands, Switzerland, the Czech Republic) within the framework of the consultations of the respective bilateral commissions (→ Article 17 (iv)). Furthermore, there is an exchange of information on operating experience with important states operating nuclear installations in Asia, such as China and Japan.

There is a regular exchange with the authorities of the contracting parties Brazil, the Netherlands, Switzerland and Spain, which operate nuclear installations of the former KWU, within the “KWU Regulators Group”.

19 (viii) Management of radioactive waste and spent fuel

In Germany, anyone who produces residual radioactive materials shall make provisions to ensure that they are utilised without detrimental effects or are disposed of as radioactive waste, as stipulated in § 9a(1) AtG. Since 1 July 2005, the shipment of spent fuel from nuclear reactors for commercial generation of electricity to facilities for reprocessing has been prohibited. The spent fuel is stored at the sites of the nuclear installations. According to the applicable legal provisions, spent fuel from nuclear reactors not used for commercial generation of electricity may be shipped to a country where research reactor fuels are supplied or manufactured. If this is not possible, this spent fuel is also to be stored.

Storage of spent fuel

Spent fuel is initially stored on-site in the spent fuel pools of the nuclear installations and then in the on-site storage facilities. With the 13th AtG amendment of 2011, eight nuclear installations were shut down following the Fukushima accident in March 2011 and one more each in 2015 and 2017. In all ten of these nuclear installations, the core has been fully unloaded. The spent fuel is partially or completely stored in the SZL.

Between 1998 and 2000, the licence holders of the nuclear installations applied to the Federal Office for Radiation Protection (BfS) as the competent licensing authority for the licences required for the storage of spent fuel in SZLs in accordance with § 6 AtG. With the Act on the Reorganisation of the Organisational Structure in the Field of Disposal of 26 July 2016, which entered into force on 30 July 2016, the responsibility for licensing procedures under § 6 AtG was transferred to the BfE. As part of the reorganisation of responsibilities in the field of waste management, the licences of the SZLs were transferred to the Bundesgesellschaft für Zwischenlagerung with effect from 1 January 2019. Nuclear and radiation protection supervision of the SZLs is carried out by the *Länder*. The SZLs are used for the dry storage of spent fuel in transport and storage casks. The capacity of the storage facilities is dimensioned such that all waste produced up to the final cessation of power plant operation can stored there until commissioning of a disposal facility. The operating period has been licensed for 40 years from the date of placing the first casks into storage. Currently, twelve SZLs are operated in Germany (→ Table 19-2).

Table 19-2 On-site storage facilities for spent fuel

On-site storage facility (SZL) at the nuclear installation	Granting of 1st licence according to § 6 AtG	Capacity HM [Mg]	Storage positions for casks (occupied end of 2018)	Start of construction	Commissioning
SZL Biblis	22.09.2003	1400	135 (101)	01.03.2004	18.05.2006
SZL Brokdorf	28.11.2003	1000	100 (33)	05.04.2004	05.03.2007
SZL Brunsbüttel[30]	28.11.2003	450	80 (20)	07.10.2003	05.02.2006
SZL Grafenrheinfeld	12.02.2003	800	88 (30)	22.09.2003	27.02.2006
SZL Grohnde	20.12.2002	1000	100 (34)	10.11.2003	27.04.2006
SZL Gundremmingen	19.12.2003	1850	192 (60)	23.08.2004	25.08.2006
SZL Isar	22.09.2003	1500	152 (59)	14.06.2004	12.03.2007
SZL Krümmel	19.12.2003	775	65 (41)	23.04.2004	14.11.2006
SZL Lingen	06.11.2002	1250	125 (47)	18.10.2000	10.12.2002
SZL Neckarwestheim	22.09.2003	1600	151 (81)	17.11.2003	06.12.2006
SZL Philippsburg	19.12.2003	1600	152 (62)	17.05.2004	19.03.2007
SZL Unterweser	22.09.2003	800	80 (39)	19.01.2004	18.06.2007

Treatment, conditioning and disposal of radioactive waste

The licence holders draw up a waste concept for the waste produced in their nuclear installations, which is submitted to the competent nuclear licensing and supervisory authority. The licence holders of the nuclear installations also carry out the treatment, conditioning and disposal of radioactive waste. In these tasks, they are partly supported by specialised industrial companies.

An inventory of all spent fuel and radioactive waste as well as estimates of future quantities, including those from decommissioning, is carried out annually. For this inventory, the volume of radioactive waste produced at the nuclear installations is also determined. Due to Directive 2011/70/Euratom and the report on the national waste management programme prepared in response to it, data collection was adapted, particularly by having to specify whether the waste is intended for the Konrad repository and by introducing a new system of categories. The reports of the Federal Republic of Germany for the review meetings of the Joint Convention regularly report comprehensively on the inventories of radioactive waste and spent fuel.

Minimisation of waste volumes

The pretreatment of radioactive waste that cannot be released from regulatory control serves to reduce the volume and to convert the primary waste into manageable intermediate products that can be conditioned for disposal. All radioactive waste produced is sorted and documented according to

30 With the ruling of the Federal Administrative Court of 16 January 2015 to reject the complaint of the Federal Office for Radiation Protection against refusal of leave to appeal in the proceedings concerning the Brunsbüttel storage facility, the judgment of the Higher Administrative Court Schleswig by which the storage licence for the Brunsbüttel storage facility has been revoked has become final. The competent nuclear licensing and supervisory authority has issued an order pursuant to § 19 AtG according to which the storage of the nuclear fuel is tolerated until January 2020. Until then, a licensed storage is the responsibility of the operator of the storage facility.

radioactivity and type. The Ordinance on the Requirements and Methods for the Disposal of Radioactive Waste (Nuclear Waste Disposal Ordinance (AtEV)) and the guideline on the control of radioactive residues and radioactive waste specify the sorting criteria and the requirements for registration, determination of activity and documentation. Thus, the waste producers can provide information about the amount of activity and the storage place of the radioactive waste at any time.

Waste management

Germany is a contracting party to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention)[31]. Report on the activities relating to radioactive waste and spent fuel management, the decommissioning of nuclear facilities and the management of disused sealed sources in Germany was last given within the framework of the Sixth Review Meeting under the Joint Convention in May 2018.

Clearance

The clearance levels for radioactive materials with minor activity and the procedures for clearance are specified in the Radiation Protection Ordinance (StrlSchV), which defines for about 700 radionuclides mass-specific clearance levels for solid and flammable liquid substances and clearance levels for

- surface contamination,
- clearance of buildings and land areas,
- clearance for disposal at landfills or in an incineration plant, and
- for metal scrap for reuse

on the basis of the 10 μSv-concept. Clearance is an official act. The necessary clearance measurements are carried out by the licence holder of a nuclear installation and are subject to the supervision by the competent regulatory authority of the *Land*, which also performs control measurements.

Implementation of the “Vienna Declaration on Nuclear Safety”

As described in Article 19 (iv), in German nuclear installations, provisions have been made for an emergency organisation and a crisis management team already before the nuclear accident at Fukushima. These are supported by external bodies, such as the crisis management team of the manufacturer and the KHG.

In addition, HMNs have been introduced in all German nuclear installations as part of the National Action Plan. These are plant-specific, serve to support the crisis management team and supplement the NHB. The procedures and strategies contained in these manuals comply with the international recommendations on SAMGs.

[31] https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/jc_6_bericht_deutschland_bf.pdf
https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/jc_6_bericht_deutschland_en_bf.pdf

Appendix 1: Nuclear installations for electricity generation and experimental and demonstration reactors

Appendix 1-1a: Nuclear installations for electricity generation in operation

	Nuclear installations for electricity generation in operation Site	**a) Licence holder** **b) Manufacturer** **c) Major shareholder**	**Type Gross capacity MWe**	**Con-struc-tion line**	**a) Date of first partial licence** **b) First criticality**
1	**Neckarwestheim 2 (GKN II)** Neckarwestheim Baden-Württemberg	a) EnBW Kernkraft GmbH (EnKK) b) KWU c) EnKK 100 %	PWR 1400	4	a) 09.11.1982 b) 29.12.1988
2	**Philippsburg 2 (KKP 2)** Philippsburg Baden-Württemberg	a) EnKK b) KWU c) EnKK 100 %	PWR 1468	3	a) 06.07.1977 b) 13.12.1984
3	**Isar 2 (KKI 2)** Essenbach Bavaria	a) PreussenElektra GmbH b) KWU c) PreussenElektra GmbH 75 %, Stadtwerke München 25 %	PWR 1485	4	a) 12.07.1982 b) 15.01.1988
4	**Gundremmingen C (KRB-II C)** Gundremmingen Bavaria	a) Kernkraftwerk Gundremmingen GmbH b) KWU c) RWE Nuclear GmbH 75 %, PreussenElektra GmbH 25 %	BWR 1344	72	a) 16.07.1976 b) 26.10.1984
5	**Grohnde (KWG)** Grohnde Lower Saxony	a) PreussenElektra GmbH b) KWU c) PreussenElektra GmbH 83.3 %, Stadtwerke Bielefeld 16.7 %	PWR 1430	3	a) 08.06.1976 b) 01.09.1984
6	**Emsland (KKE)** Lingen Lower Saxony	a) Kernkraftwerke Lippe-Ems b) KWU c) RWE Nuclear GmbH 87.5 %, PreussenElektra GmbH 12.5 %	PWR 1406	4	a) 04.08.1982 b) 14.04.1988
7	**Brokdorf (KBR)** Brokdorf Schleswig-Holstein	a) PreussenElektra GmbH b) KWU c) PreussenElektra GmbH 80 %, Vattenfall 20 %	PWR 1480	3	a) 25.10.1976 b) 08.10.1986

Appendix 1-1b: Nuclear installations for electricity generation permanently shut down, no decommissioning licence granted yet

Nuclear installations for electricity generation shut down Site		**a) Licence holder** **b) Manufacturer** **c) Major shareholder**	**Type Gross capacity MWe**	**Con-struction line**	**a) Date of first partial licence** **b) First criticality** **c) Date of shutdown**
1	**Krümmel (KKK)** Krümmel Schleswig-Holstein	a) Kernkraftwerk Krümmel GmbH & Co. oHG b) KWU c) Vattenfall 50 %, PreussenElektra GmbH 50 %	BWR 1402	69	a) 18.12.1973 b) 14.09.1983 c) 06.08.2011

Appendix 1-2: Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning

	Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning Site	**a) Last licence holder** **b) Manufacturer** **c) Licence holder decommissioning**	**Type Gross capacity MWe**	**a) First criticality** **b) Shutdown** **c) First decommissioning licence**
1	**Kompakte natriumgekühlte Reaktoranlage (KNK II)** Karlsruhe Baden-Württemberg	a) Kernkraftwerk Betriebsgesellschaft mbH b) Interatom c) Kerntechnische Entsorgung Karlsruhe GmbH	SNR 21	a) 10.10.1977 b) 23.08.1991 c) 26.08.1993
2	**Mehrzweckforschungsreaktor (MZFR)** Eggenstein-Leopoldshafen Baden-Württemberg	a) Kernkraftwerk Betriebsgesellschaft mbH b) Siemens/KWU c) Kerntechnische Entsorgung Karlsruhe GmbH	Pressurised heavy water reactor 57	a) 29.09.1965 b) 03.05.1984 c) 17.11.1987
3	**Neckarwestheim I (GKN I)** Neckarwestheim Baden-Württemberg	a) EnKK b) KWU c) EnKK 100 %	PWR 840	a) 26.05.1976 b) 06.08.2011 c) 03.02.2017
4	**Philippsburg 1 (KKP 1)** Philippsburg Baden-Württemberg	a) EnKK b) KWU c) EnKK 100 %	BWR 926	a) 09.03.1979 b) 06.08.2011 c) 07.04.2017
5	**Obrigheim (KWO)** Obrigheim Baden-Württemberg	a) EnKK b) Siemens c) EnKK	PWR 357	a) 22.09.1968 b) 11.05.2005 c) 28.08.2008
6	**Gundremmingen A (KRB A)** Gundremmingen Bavaria	a) Kernkraftwerk RWE-Bayernwerk b) AEG/General Electric c) Kernkraftwerk Gundremmingen GmbH	BWR 250	a) 14.08.1966 b) 13.01.1977 c) 26.05.1983
7	**Gundremmingen B (KRB-II B)** Gundremmingen Bavaria	a) Kernkraftwerk Gundremmingen GmbH b) KWU c) RWE Nuclear GmbH 75 %, PreussenElektra GmbH 25 %	BWR 1344	a) 09.03.1984 b) 31.12.2017 c) 19.03.2019
8	**Grafenrheinfeld (KKG)** Grafenrheinfeld Bavaria	a) E.ON Kernkraft GmbH b) KWU c) PreussenElektra GmbH	PWR 1345	a) 09.12.1981 b) 27.06.2015 c) 11.04.2018
9	**Isar 1 (KKI 1)** Essenbach Bavaria	a) E.ON Kernkraft GmbH b) KWU c) PreussenElektra GmbH	BWR 912	a) 20.11.1977 b) 06.08.2011 c) 17.01.2017
10	**Rheinsberg (KKR)** Rheinsberg Brandenburg	a) Energiewerke Nord GmbH b) VEB Kernkraftwerksbau Berlin c) EWN Entsorgungswerk für Nuklearanlagen GmbH	PWR (WWER) 70	a) 11.03.1966 b) 01.06.1990 c) 28.04.1995
11	**Biblis A (KWB A)** Biblis Hesse	a) RWE Power AG b) KWU c) RWE Nuclear GmbH	PWR 1225	a) 16.07.1974 b) 06.08.2011 c) 30.03.2017

Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning Site		a) Last licence holder b) Manufacturer c) Licence holder decommissioning	Type Gross capacity MWe	a) First criticality b) Shutdown c) First decommissioning licence
12	**Biblis B (KWB B)** Biblis Hesse	a) RWE Power AG b) KWU c) RWE Nuclear GmbH	PWR 1300	a) 25.03.1976 b) 06.08.2011 c) 30.03.2017
13	**Greifswald 1 (KGR 1)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau c) EWN Entsorgungswerk für Nuklearanlagen GmbH	PWR (WWER) 440	a) 03.12.1973 b) 18.12.1990 c) 30.06.1995
14	**Greifswald 2 (KGR 2)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau c) EWN Entsorgungswerk für Nuklearanlagen GmbH	PWR (WWER) 440	a) 03.12.1974 b) 14.02.1990 c) 30.06.1995
15	**Greifswald 3 (KGR 3)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau c) EWN Entsorgungswerk für Nuklearanlagen GmbH	PWR (WWER) 440	a) 06.10.1977 b) 28.02.1990 c) 30.06.1995
16	**Greifswald 4 (KGR 4)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau c) EWN Entsorgungswerk für Nuklearanlagen GmbH	PWR (WWER) 440	a) 22.07.1979 b) 02.06.1990 c) 30.06.1995
17	**Greifswald 5 (KGR 5)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau c) EWN Entsorgungswerk für Nuklearanlagen GmbH	PWR (WWER) 440	a) 26.03.1989 b) 30.11.1989 c) 30.06.1995
18	**Lingen (KWL)** Lingen Lower Saxony	a) Kernkraftwerk Lingen GmbH b) AEG/KWU c) Kernkraftwerk Lingen GmbH	BWR 252	a) 31.01.1968 b) 05.01.1977 c) 21.11.1985 (safe enclosure) 21.12.2015 (dismantling)
19	**Stade (KKS)** Stade Lower Saxony	a) E.ON Kernkraft GmbH b) KWU c) PreussenElektra GmbH	PWR 672	a) 08.01.1972 b) 14.11.2003 c) 07.09.2005
20	**Unterweser (KKU)** Esenshamm Lower Saxony	a) E.ON Kernkraft GmbH b) KWU c) PreussenElektra GmbH	PWR 1410	a) 16.09.1978 b) 06.08.2011 c) 05.02.2018
21	**Atomversuchskraftwerk (AVR)** Jülich North Rhine-Westphalia	a) Arbeitsgemeinschaft Versuchsreaktor GmbH b) BBC/Krupp Reaktorbau c) Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH	HTR 15	a) 26.08.1966 b) 31.12.1988 c) 09.03.1994 (safe enclosure) 31.03.2009 (dismantling)

Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning Site		a) Last licence holder b) Manufacturer c) Licence holder decommissioning	Type Gross capacity MWe	a) First criticality b) Shutdown c) First decommissioning licence
22	**Thorium-Hochtemperaturreaktor (THTR 300)** Hamm-Uentrop North Rhine-Westphalia	a) Hochtemperatur Kernkraftwerk GmbH b) BBC/HRB/NUKEM c) Hochtemperatur Kernkraftwerk GmbH	HTR 308	a) 13.09.1983 b) 29.09.1988 c) 22.10.1993 21.05.1997 (safe enclosure)
23	**Würgassen (KWW)** Würgassen North Rhine-Westphalia	a) PreussenElektra AG b) AEG/KWU c) PreussenElektra GmbH	BWR 670	a) 22.10.1971 b) 26.08.1994 c) 14.04.1997
24	**Mülheim-Kärlich (KMK)** Mülheim-Kärlich Rhineland-Palatinate	a) RWE Energie AG b) BBR c) RWE Nuclear GmbH	PWR 1302	a) 01.03.1986 b) 09.09.1988 c) 16.07.2004
25	**Brunsbüttel (KKB)** Brunsbüttel Schleswig-Holstein	a) Kernkraftwerk Brunsbüttel GmbH & Co. oHG b) AEG/KWU c) Kernkraftwerk Brunsbüttel GmbH & Co. oHG	BWR 806	a) 23.06.1976 b) 06.08.2011 c) 21.12.2018

Appendix 1-3: Nuclear installations for electricity generation completely dismantled and released from the scope of the AtG

Nuclear installations for electricity generation completely dismantled and released from the scope of the AtG Site		**a) Last licence holder** **b) Manufacturer**	**Type** **Gross capacity** **MWe**	**a) First criticality** **b) Shutdown** **c) Release from AtG**
1	**Heißdampfreaktor Großwelzheim (HDR)** Karlstein Bavaria	a) Forschungszentrum Karlsruhe b) AEG	Superheated steam cooled reactor 25	a) 14.10.1969 b) 20.04.1971 c) 14.05.1998
2	**Niederaichbach (KKN)** Niederaichbach Bavaria	a) Forschungszentrum Karlsruhe b) Siemens	Pressure tube reactor 106	a) 17.12.1972 b) 31.07.1974 c) 17.08.1994
3	**Versuchsatomkraft-werk Kahl (VAK)** Karlstein Bavaria	a) Versuchsatomkraftwerk Kahl b) AEG/General Electric	BWR 16	a) 13.11.1960 b) 25.11.1985 c) 17.05.2010

Appendix 1-4: Abandoned projects

Abandoned projects Site		**a) Last licence holder** **b) Manufacturer**	**Type** **Gross capacity** **MWe**	**Status**
1	**Greifswald 6 (KGR 6)** Lubmin Mecklenburg- Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksan-lagenbau	PWR (WWER) 440	Project abandoned
2	**Greifswald 7 (KGR 7)** Lubmin Mecklenburg- Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksan-lagenbau	PWR (WWER) 440	Project abandoned
3	**Greifswald 8 (KGR 8)** Lubmin Mecklenburg-, Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksan-lagenbau	PWR (WWER) 440	Project abandoned
4	**SNR 300** Kalkar North Rhine-Westphalia	a) Schnell-Brüter Kernkraft-werksgesellschaft b) Interatom/Belgonucléaire/ Neratoom	SNR 327	Project abandoned 20.03.1991
5	**Stendal A** Stendal Saxony-Anhalt	a) Altmark Industrie b) VEB Kombinat Kraftwerksan-lagenbau	PWR (WWER) 1000	Project abandoned
6	**Stendal B** Stendal Saxony-Anhalt	a) Altmark Industrie b) VEB Kombinat Kraftwerksan-lagenbau	PWR (WWER) 1000	Project abandoned

Appendix 2: Research reactors

Appendix 2-1a: Research reactors in operation

Research reactor Site		Licence holder	Reactor type Thermal output [MWth] th. n-flux [$cm^{-2}s^{-1}$]	First criticality
1	**SUR-FW** Furtwangen Baden-Württemberg	Hochschule Furtwangen	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	28.06.1973
2	**SUR-S** Stuttgart Baden-Württemberg	Universität Stuttgart Institut für Kernenergetik und Energiesysteme	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	24.08.1964
3	**SUR-U** Ulm Baden-Württemberg	Fachhochschule Ulm Labor für Strahlenmess-technik und Reaktortech-nik	SUR-100 $1 \cdot 10^{-7}$ $5 \cdot 10^{6}$	01.12.1965
4	**FRM II** Garching Bavaria	Technische Universität München	Swimming pool/compact core 20 $8 \cdot 10^{14}$	02.03.2004
5	**BER II** Berlin	Helmholtz-Zentrum Berlin für Materialien und Ener-gie GmbH	Swimming pool/MTR 10 $2 \cdot 10^{14}$	09.12.1973
6	**FRMZ** Mainz Rhineland-Palatinate	Universität Mainz Institut für Kernchemie	Swimming pool/TRIGA Mark II 0.1 $4 \cdot 10^{12}$	03.08.1965
7	**AKR-2** Dresden Saxony	Technische Universität Dresden Institut für Energietechnik	SUR-type $2 \cdot 10^{-6}$ $3 \cdot 10^{7}$	22.03.2005 (AKR-1: 28.07.1978)

Appendix 2-1b: Research reactors permanently shut down

Research reactors perma-nently shut down, no de-commissioning licence granted yet Site		Licence holder	Reactor type Thermal output [MWth] th. n-flux [$cm^{-2}s^{-1}$]	a) First criticality b) Date of shutdown c) Application for de-commissioning
1	**SUR-AA** Aachen North Rhine-Westphalia	RWTH Aachen Institut für elektrische An-lagen und Energiewirt-schaft	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 22.09.1965 b) since 2002 out of opera-tion and since 2008 free of nuclear fuel c) 2010
2	**FRG-1** Geesthacht Schleswig-Holstein	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenfor-schung GmbH	Swimming pool/MTR 5 $1 \cdot 10^{14}$	a) 23.10.1958 b) 28.06.2010 c) 21.03.2013
3	**FRG-2** Geesthacht Schleswig-Holstein	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenfor-schung GmbH	Swimming pool/MTR 15 $2 \cdot 10^{14}$	a) 16.03.1963 b) 28.01.1993[32] c) 21.03.2013[33]

32 Application for decommissioning and partial dismantling

33 Application for dismantling of the research reactor facility (consisting of the FRG-1 and parts of the FRG-2 still existing)

Appendix 2-2: Research reactors under decommissioning

	Research reactors under decommissioning Site	**Licence holder**	**Reactor type** **Thermal output [MWth]** **th. n-flux [cm-2s-1]**	**a) First criticality** **b) Shutdown** **c) First decommissioning licence**
1	**FR-2** Eggenstein-Leopolds-hafen Baden-Württemberg	Kerntechnische Entsorgung Karlsruhe	Tank-type/D_2O reactor 44 $1 \cdot 10^{14}$	a) 07.03.1961 b) 21.12.1981 c) 03.07.1986 20.11.1996 (safe enclosure)
2	**FRM** Garching Bavaria	Technische Universität München	Swimming pool/MTR 4 $7 \cdot 10^{13}$	a) 31.10.1957 b) 28.07.2000 c) 03.04.2014
3	**FRN** Oberschleißheim Bavaria	Helmholtz Zentrum München – Deutsches Forschungszentrum für Gesundheit und Umwelt GmbH	Swimming pool/TRIGA Mark III 1 $3 \cdot 10^{13}$	a) 23.08.1972 b) 16.12.1982 c) 30.05.1983 24.05.1984 (safe enclosure)
4	**FMRB** Braunschweig Lower Saxony	Physikalisch Technische Bundesanstalt Braunschweig	Swimming pool/MTR 1 $6 \cdot 10^{12}$	a) 03.10.1967 b) 19.12.1995 c) 02.03.2001 28.07.2005 facility released from AtG except for storage facility
5	**SUR-H** Hannover Lower Saxony	Leibniz Universität Hannover Institut für Kerntechnik und zerstörungsfreie Prüfverfahren	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 09.12.1971 b) since 2008 out of operation und free of nuclear fuel c) 04.09.2017
6	**FRJ-2 (DIDO)** Jülich North Rhine-Westphalia	Jülicher Entsorgungsgesellschaft für Nuklearanlagen mbH	Tank-type/D_2O reactor 23 $2 \cdot 10^{14}$	a) 14.11.1962 b) 02.05.2006 c) 20.09.2012
7	**RFR** Rossendorf Saxony	VKTA - Strahlenschutz, Analytik und Entsorgung Rossendorf e.V.	Tank-type/WWR-S(M) 10 $1 \cdot 10^{14}$	a) 16.12.1957 b) 27.06.1991 c) 30.01.1998

Appendix 2-3: Research reactors, decommissioning completed or released from the scope of the AtG

Decommissioning completed or released from the scope of the AtG Site		**Last Licence holder**	**Reactor type** **Thermal output [MWth]** **th. n-flux [$cm^{-2}s^{-1}$]**	**a) First criticality** **b) Shutdown** **c) Decommissioning completed**
1	**SNEAK** Eggenstein-Leopoldshafen Baden-Württemberg	Kernforschungszentrum Karlsruhe	Homogeneous reactor $1 \cdot 10^{-3}$ $7 \cdot 10^{6}$	a) 15.12.1966 b) 11/1985 c) 06.05.1987
2	**SUAK** Eggenstein-Leopoldshafen Baden-Württemberg	Kernforschungszentrum Karlsruhe	Subcritical assembly	a) 20.11.1964 b) 07.12.1978
3	**STARK** Eggenstein-Leopoldshafen Baden-Württemberg	Kernforschungszentrum Karlsruhe	Argonaut $1 \cdot 10^{-5}$ $1 \cdot 10^{8}$	a) 11.01.1963 b) 03/1976 c) 1977
4	**SUR-KA** Eggenstein-Leopoldshafen Baden-Württemberg	Kernforschungszentrum Karlsruhe	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 07.03.1966 b) 09/1996 c) 26.06.1998
5	**TRIGA HD I** Heidelberg Baden-Württemberg	Deutsches Krebsforschungszentrum	Swimming pool/TRIGA Mark I 0.25 $1 \cdot 10^{13}$	a) 26.08.1966 b) 31.03.1977 c) 13.12.2006
6	**TRIGA HD II** Heidelberg Baden-Württemberg	Deutsches Krebsforschungszentrum	Swimming pool/TRIGA Mark I 0.25 $1 \cdot 10^{13}$	a) 28.02.1978 b) 30.11.1999 c) 13.12.2006
7	**AEG Nullenergie Reaktor (TKA)** Karlstein Bavaria	Kraftwerk Union	Tank-type/critical assembly $1 \cdot 10^{-4}$ $1 \cdot 10^{8}$	a) 23.06.1967 b) 1973 c) 21.12.1981
8	**AEG Prüfreaktor PR-10** Karlstein Bavaria	Kraftwerk Union	Argonaut $1.8 \cdot 10^{-4}$ $3 \cdot 10^{10}$	a) 27.01.1961 b) 1976 c) 22.02.1978
9	**SAR** Garching Bavaria	Technische Universität München	Argonaut $1 \cdot 10^{-3}$ $2 \cdot 10^{11}$	a) 23.06.1959 b) 31.10.1968 c) 20.03.1998
10	**SUA** Garching Bavaria	Technische Universität München	Subcritical assembly	a) 06/1959 b) 1968 c) 20.03.1998
11	**SUR-M** Garching Bavaria	Technische Universität München	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 28.02.1962 b) 10.08.1981 c) 20.03.1998
12	**BER I** Berlin	Hahn-Meitner-Institut	Homogeneous reactor 0.05 $2 \cdot 10^{12}$	a) 24.07.1958 b) 1972 c) 23.04.1974

	Decommissioning completed or released from the scope of the AtG Site	Last Licence holder	Reactor type Thermal output [MWth] th. n-flux [$cm^{-2}s^{-1}$]	a) First criticality b) Shutdown c) Decommissioning completed
13	**SUR-B** Berlin	Technische Universität Berlin, Institut für Energietechnik	SUR-100 $1 \cdot 10^{-7}$ $5 \cdot 10^{6}$	a) 26.07.1963 b) 15.10.2007 c) 16.04.2013
14	**SUR-HB** Bremen	Hochschule Bremen	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 10.10.1967 b) 17.06.1993 c) 16.04.2013
15	**SUR-HH** Hamburg	Fachhochschule Hamburg	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 15.01.1965 b) 08/1992 c) 12/1999
16	**FRF 1** Frankfurt Hesse	Johann Wolfgang Goethe-Universität Frankfurt	Homogeneous reactor 0.05 $1 \cdot 10^{12}$	a) 10.01.1958 b) 19.03.1968 c) 31.10.2006
17	**FRF 2** Frankfurt Hesse	Johann Wolfgang Goethe-Universität Frankfurt	Modified TRIGA 1 $3 \cdot 10^{13}$	a) no criticality b) project abandoned, no operation c) 31.10.2006
18	**SUR-DA** Darmstadt Hesse	Technische Hochschule Darmstadt	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 23.09.1963 b) 22.02.1985 c) 29.11.1996
19	**FRH** Hannover Lower Saxony	Medizinische Hochschule Hannover	Swimming pool/TRIGA Mark I 0.25 $9 \cdot 10^{12}$	a) 31.01.1973 b) 18.12.1996 c) 13.03.2008
20	**ADIBKA (L77A)** Jülich North Rhine-Westphalia	Hochtemperatur Reaktorbau Köln	Homogeneous reactor $1 \cdot 10^{-4}$ $3 \cdot 10^{8}$	a) 18.03.1967 b) 30.10.1972 c) 12/1977
21	**FRJ-1 (MERLIN)** Jülich North Rhine-Westphalia	Forschungszentrum Jülich	Swimming pool/MTR 10 $1 \cdot 10^{14}$	a) 24.02.1962 b) 22.03.1985 c) 23.11.2007
22	**KAHTER** Jülich North Rhine-Westphalia	Kernforschungsanlage Jülich	Critical assembly $1 \cdot 10^{-4}$ $2 \cdot 10^{8}$	a) 02.07.1973 b) 03.02.1984 c) 06/1988
23	**KEITER** Jülich North Rhine-Westphalia	Kernforschungsanlage Jülich	Critical assembly $1 \cdot 10^{-6}$ $2 \cdot 10^{7}$	a) 15.06.1971 b) 1982 c) 06/1988
24	**RAKE** Rossendorf Saxony	Verein für Kernverfahrenstechnik und Analytik Rossendorf e.V. (VKTA)	Tank-type/Critical assembly $1 \cdot 10^{-5}$ $1 \cdot 10^{8}$	a) 03.10.1969 b) 26.11.1991 c) 28.10.1998
25	**RRR** Rossendorf Saxony	Verein für Kernverfahrenstechnik und Analytik Rossendorf e.V. (VKTA)	Argonaut $1 \cdot 10^{-3}$ $2 \cdot 10^{11}$	a) 16.12.1962 b) 25.09.1991 c) 11.05.2000
26	**ZLFR** Zittau Saxony	Hochschule Zittau/Görlitz, Fachbereich Maschinenwesen	Tank-type/WWR-M $1 \cdot 10^{-5}$ $1 \cdot 10^{8}$	a) 25.05.1979 b) 24.03.2005 c) 03.05.2006

Decommissioning completed or released from the scope of the AtG Site		Last Licence holder	Reactor type Thermal output [MWth] th. n-flux [$cm^{-2}s^{-1}$]	a) First criticality b) Shutdown c) Decommissioning completed
27	**ANEX** Geesthacht Schleswig-Holstein	Forschungszentrum Geesthacht	Critical assembly $1 \cdot 10^{-7}$ $2 \cdot 10^{8}$	a) 05/1964 b) 05.02.1975 c) 01/1980
28	**NS OTTO HAHN** Geesthacht Schleswig-Holstein	Forschungszentrum Geesthacht	PWR ship reactor 38 $3 \cdot 10^{13}$	a) 26.08.1968 b) 22.03.1979 c) 01.09.1982
29	**SUR-KI** Kiel Schleswig-Holstein	Fachhochschule Kiel	SUR-100 $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 29.03.1966 b) 11.12.1997 c) 02.04.2008

Appendix 3: Safety-related design characteristics, PWR and BWR

1. Reactor coolant pressure boundary **PWR**

Design characteristics	Construction line 3	Construction line 4
Number of loops	Four	Four
Suitability of the construction for non-destructive testing	Yes	
Construction		
– Seamless forged rings for vessels	Reactor pressure vessel, steam generator, pressuriser	
– Seamless pipes	Main coolant line	
Materials		
– Ageing-resistant ferritic fine-grained structural steels with stabilised austenitic cladding	All components and pipes with nominal diameter above 400 mm	Like construction line 3, but with optimised qualities
– Ageing-resistant stabilised austenitic steels	All pipes with nominal diameter below 400 mm and component internals	
– Corrosion-resistant steam generator tube material (Incoloy 800)	Yes	
Application of the break preclusion concept	Prior to commissioning	From the start of planning
Reduction of embrittlement from neutron radiation exposure	Optimised welding material and enlargement of water gap in the reactor pressure vessel to reduce neutron fluence	

1. Reactor coolant pressure boundary BWR

Design characteristics	Construction line 72
Recirculation pumps integrated in the reactor pressure vessel	Eight
Suitability of the construction for destructive testing	Yes
Construction	
– Seamless forged rings for reactor pressure vessels	Yes, except: closure head, bottom head
– Seamless pipes	Yes
Materials	
– Ageing-resistant ferritic fine-grained structural steels	Reactor pressure vessel, main steam and feedwater pipes
– Ageing-resistant stabilised austenitic steels	Pipes[34], partly refitted by replacements, in addition reactor pressure vessel internals and cladding
Application of the break preclusion concept	From the start of planning; under review[35]
Reduction of embrittlement from neutron radiation exposure	Special fuel management (low leakage loading)

[34] For KRB II: Only stabilised austenitic pipes are used.

[35] For KRB II: The break preclusion concept was approved by the competent authority with a modification licence.

2. Emergency core cooling **PWR**

Design characteristics	Construction line 3	Construction line 4
Number of emergency core cooling trains/capacity	Four trains at least 50 % each	
Pump head of high-pressure pumps	approx. 110 bar	
Secondary circuit shutdown in the case of small leaks	Fully automatic	
Number of borated water flooding tanks	Four, in some cases twin tanks or four flooding pools	
Pump head of low-pressure injection pumps	approx. 10 bar	
Accumulators (injection pressure)	Two per loop (25 bar)	
Sump pipe before outer penetration isolation valve	Guard pipe construction with leakage monitoring	
Place of installation of the active emergency core cooling systems	Annulus	

2. Emergency core cooling **BWR**

Design characteristics	Construction line 72
Number of trains of the high-pressure safety injection system (capacity)	Three trains (electric pumps,3x70 kg/s)
Pressure relief	Eleven safety and pressure relief valves, additionally three motorised pressure relief valves
Intermediate-pressure injection system	One train (additional independent residual heat removal system; electric pump, 40 bar)
Number of low-pressure emergency core cooling trains/capacity	Three trains of 100 % each
Backfeed from containment sump	Yes, via passive systems with four overflow pipes
Place of installation of the emergency core cooling systems	In separate rooms of the reactor building, intermediate-pressure system in a bunkered building

3. Containment vessel PWR

Design characteristics	Construction line 3	Construction line 4
Type	Spherical steel vessel with surrounding concrete enclosure, annular gap and constant internal subatmospheric pressure	
Design pressure (overpressure)	5.3 bar	
Design temperature	145°C	
Material of steel vessel (main structure)	FG51WS; 15MnNi63; Aldur 50/65D	15MnNi63
Wall thickness of steel vessel in the spherical region remote from dis-continuities	up to 38 mm	38 mm
Airlocks		
– Equipment airlock	Double seals with evacuation	
– Personnel airlock	Double seals with evacuation	
– Emergency airlock	One with double seals and evacuation	
Penetrations		
– Main steam line	One isolation valve outside of containment	
– Feedwater line	One isolation valve each inside and outside of containment	
– Emergency core cooling and auxiliary systems	With a few exceptions, one isolation valve each inside and outside of containment	One isolation valve each inside and outside of containment
– Ventilation systems	One isolation valve each inside and outside of containment	

3. Containment vessel **BWR**

Design characteristics	Construction line 72
Type	Cylindrical pre-stressed concrete shell with annular pressure suppression pool
Design pressure (overpressure)	3.3 bar
Design temperature	approx. 150 °C
Material of steel vessel (main structure)	TTSTE29
Wall thickness of steel vessel outside the concrete support	8 mm steel liner
Number of active pipes in the pressure suppression pool	63
Immersion depth of pipes in the pressure suppression pool	4.0 m
Inertisation of the air in the pressure suppression pool	Yes
Inertisation of the drywell	No
Airlocks	**In all cases double seals with evacuation**
– Equipment airlock	None
– Personnel airlock	Leading to control rod drive chamber, for personnel and for equipment transports
– Emergency airlock	Two, one from the control rod drive chamber and one above the pressure suppression pool
Penetrations	
– Main steam line/feedwater line	One isolation valve each inside and outside of containment
– Emergency core cooling and auxiliary systems	Emergency core cooling system in the area of the pressure suppression pool and several small pipes with two isolation valves outside of containment, otherwise one isolation valve each inside and outside of containment
– Ventilation	Two isolation valves outside of containment

4. Limitations and safety I&C, including reactor protection system

PWR

4.1 Limitations

Design characteristics	Construction line 3	Construction line 4
Reactor power limitation	Yes	
Control rod movement limitation	Yes (monitoring of shutdown reactivity)	
Limitations of coolant pressure, coolant mass and temperature gradient	Yes	

4.2 Safety I&C, including reactor protection system

Design characteristics	Construction line 3	Construction line 4
Actuation criteria derived from accident analysis	Yes	
Different physical actuation criteria for reactor protection system	Yes, or diverse actuation channels	
Failure combinations	Random failure, systematic failure, consequential failures, non-availability due to maintenance	
Testing of reactor protection system is possible during power operation	Yes, largely by automatic self-monitoring (of functional readiness)	
Actuation of protection systems	Apart from a few exceptions, all actions are performed automatically, and manual actions are not required within the first 30 min after the onset of an accident.	

4. Limitations and safety I&C, including reactor protection system

BWR

4.1 Limitations

Design characteristics	Construction line 72
Fixed reactor power limitation	Yes, speed reduction of forced-circulation pumps
Variable reactor power limitation	Yes, control rod withdrawal interlock, start-up interlock of forced-circulation pumps
Local power limitation	Yes, control rod withdrawal interlock and speed reduction of forced-circulation pumps

4.2 Safety I&C, including reactor protection system

Design characteristics	Construction line 72
Actuation criteria derived from accident analysis	Yes
Different physical actuation criteria for reactor protection system	Yes, or diversified actuation channels
Failure combinations	Random failure, systematic failure, consequential failures, non-availability due to maintenance
Testing of reactor protection system is possible during power operation	Yes, largely by automatic self-monitoring (of functional readiness)
Actuation of protection systems	Apart from a few exceptions, all actions are performed automatically, and manual actions are not required within the first 30 min after the onset of an accident.

5.1 Electrical power supply **PWR**

Design characteristics	Construction line 3	Construction line 4
Number of independent off-site power supplies	Three at least	
Generator circuit breaker	Yes	
Auxiliary station supply in the case of off-site power loss	Yes, load rejection to auxiliary station supply	
Emergency power supply	Four trains with one diesel each (4x50 %)	
Additional emergency power supply for the control of external impacts	Four trains with one diesel each (4x50 %)	
Uninterruptible DC power supply	3x four trains	
Protected DC power supply	10 h at least	
Separation of trains	Largely non-intermeshed emergency power supply, physical separation of the emergency power supply grids	

5.2 Electrical power supply BWR

Design characteristics	Construction line 72
Number of independent off-site power supplies	At least three independent off-site power supplies
Generator circuit breaker	Yes
Auxiliary station supply in the case of off-site power loss	Yes, load rejection to auxiliary station supply
Emergency power supply	Six trains with one diesel each
Additional emergency power supply for the control of external impacts	Three trains with one diesel each
Uninterruptible DC power supply	Three (220 V) + seven (24 V) trains
Protected DC power supply	2 h at least, in practice, significantly longer periods were determined.
Separation of trains	Non-intermeshed emergency power supply, physical separation of emergency power redundancies

6.1 Protection against external hazards PWR

Design characteristics	Construction line 3	Construction line 4
Earthquake	Design of components important to safety in accordance with site-specific load assumptions	
Aircraft crash and blast wave	Design in accordance with rules and regulations (→ Article 17 (i)), emergency systems integrated the safety systems	

6.2 Protection against external hazards BWR

Design characteristics	Construction line 72
Earthquake	Design of components important to safety in accordance with site-specific load assumptions
Aircraft crash and blast wave	Design in accordance with rules and regulations (→ Article 17 (i)), emergency systems integrated the safety systems