Federal Ministry
for the Environment, Climate Action,
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Report by the Government of the Federal Republic of Germany for the 10th Review Meeting of the Convention on Nuclear Safety in April 2026

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Abbreviations

ALARA	As Low As Reasonably Achievable
AtG	Atomgesetz Atomic Energy Act
AtGÄndG	Gesetz zur Änderung des Atomgesetzes Act Amending the 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
AVT	All Volatile Treatment
AVR	Arbeitsgemeinschaft Versuchsreaktor Jülich Experimental reactor at Jülich
AVV	Allgemeine Verwaltungsvorschrift General administrative provision
BASE	Bundesamt für die Sicherheit der nuklearen Entsorgung (früher BfE) Federal Office for the Safety of Nuclear Waste Management (formerly BfE)
BBK	Bundesamt für Bevölkerungsschutz und Katastrophenhilfe Federal Office of Civil Protection and Disaster Assistance
BfE	Bundesamt für kerntechnische Entsorgungssicherheit (heute BASE) Federal Office for the Safety of Nuclear Waste Management (now BASE)
BfS	Bundesamt für Strahlenschutz Federal Office for Radiation Protection
BGE	Bundesgesellschaft für Endlagerung mbH
BGZ	Bundesgesellschaft für Zwischenlagerung mbH
BHB	Betriebshandbuch Operating manual
BImSchG	Bundes-Immissionsschutzgesetz Federal Immission Control Act
BMBF	Bundesministerium für Bildung und Forschung (bis Mai 2025) Federal Ministry of Education and Research (until May 2025)
BMFTR	Bundesministerium für Forschung, Technologie und Raumfahrt (seit Mai 2025) Federal Ministry of Research, Technology and Space (since May 2025)
BMG	Bundesministerium für Gesundheit Federal Ministry of Health
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Juni 1986 bis Dezember 2013 und März 2018 bis Dezember 2021) Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (June 1986 to December 2013 and March 2018 to December 2021)

BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Dezember 2013 bis März 2018) Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (December 2013 to March 2018)
BMUKN	Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit (seit Mai 2025) Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (since May 2025)
BMUV	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (Dezember 2021 bis Mai 2025) Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (December 2021 to May 2025)
BMWi	Bundesministerium für Wirtschaft und Energie (heute BMWK) Federal Ministry for Economic Affairs and Energy (now BMWK)
BMWK	Bundesministerium für Wirtschaft und Klimaschutz (früher BMWi) Federal Ministry for Economic Affairs and Climate Action (formerly BMWi)
BWR	Boiling Water Reactor
CBSS	Council of the Baltic Sea States
CCF(s)	Common Cause Failure(s)
CNS	Convention on Nuclear Safety
DIN	Deutsches Institut für Normung German Institute for Standardization
EGOE	Expert Group on Operating Experience of the OECD/NEA
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
EnKK	EnBW Kernkraftwerk GmbH
ENSREG	European Nuclear Safety Regulator Group
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
EURDEP	EUropean Radiological Data Exchange Platform
FA/FAs	Fuel Assembly/Fuel Assemblies
gGmbH	Gemeinnützige Gesellschaft mit beschränkter Haftung Non-profit limited liability company
GfS	Gesellschaft für Simulatorschulung mbH (Company for Simulator Training)
GG	Grundgesetz Basic Law of the Federal Republic of Germany

GKN	Kernkraftwerk Neckarwestheim Neckarwestheim nuclear power plant
GmbH	Gesellschaft mit beschränkter Haftung Limited liability company
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH
HGF	Helmholtz-Gemeinschaft Helmholtz Association
HMN	Handbuch für mitigative Notfallmaßnahmen Accident mitigation manual
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IfSG	Infektionsschutzgesetz Infection Protection Act
IMIS	Integriertes Mess- und Informationssystem zur Überwachung der Umweltradioaktivität Integrated Measuring and Information System for the Monitoring of Environmental Radioactivity
IMS	Integriertes Managementsystem Integrated Management System
INES	International Nuclear and Radiological Event Scale
INEX	International Nuclear Emergency Exercises
INFCIRC	Information Circular
IRMIS	International Radiation Monitoring Information System
IRRS	Integrated Regulatory Review Service
IRS	International Reporting System
ISI	In-Service Inspection
ISO	International Organization for Standardization
Joint Convention	Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
KBR	Kernkraftwerk Brokdorf Brokdorf nuclear power plant
KFÜ	Kernkraftwerks-Fernüberwachungssystem Remote monitoring system for nuclear power plant
KHG	Kerntechnische Hilfsdienst GmbH
KKB	Kernkraftwerk Brunsbüttel Brunsbüttel nuclear power plant
KKG	Kernkraftwerk Grafenrheinfeld Grafenrheinfeld nuclear power plant
KKE	Kernkraftwerk Emsland Emsland nuclear power plant
KKI	Kernkraftwerk Isar Isar nuclear power plant
KKK	Kernkraftwerk Krümmel Krümmel nuclear power plant

KKP	Kernkraftwerk Philippsburg Philippsburg nuclear power plant
KKU	Kernkraftwerk Unterweser Unterweser nuclear power plant
KOMFORT	Katalog zur Erfassung organisationaler und menschlicher Faktoren bei Inspektionen vor Ort Catalogue for recording organisational and human factors during on-site inspections
KRB	Kernkraftwerk Gundremmingen Gundremmingen nuclear power plant
KTA	Kerntechnischer Ausschuss Nuclear Safety Standards Commission
KWB	Kernkraftwerk Biblis Biblis nuclear power plant
KWG	Kernkraftwerk Grohnde Grohnde nuclear power plant
KWU	Kraftwerk Union AG
LAA	Länderausschuss für Atomkernenergie *Länder* Committee for Nuclear Energy
MoWaS	Modulares Warnsystem Modular warning system
MOX	Mixed oxide
MSK-Skala	Medwedew-Sponheuer-Kárník scale
MTO	Man, Technology, Organisation
NCFSI	Non-conforming, Counterfeit, Fraudulent, or Suspect Items
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
NSGC	Nuclear Security Guidance Committee
OECD/NEA	Organisation for Economic Co-operation and Development/Nuclear Energy Agency
PBO	Personelle Betriebsorganisation Plant personnel organisation
PlanSiG	Planungssicherstellungsgesetz Planning Security Act
PNS	Portal for Nuclear Safety
PSA	Probabilistic Safety Analysis
PWR	Pressurised Water Reactor
QV	Qualification network Qualifizierungsverbund

REI	Richtlinie zur Emissions- und Immissionsüberwachung kerntechnischer Anlagen Guideline on Emission and Immission Monitoring of Nuclear Installations
RHWG	Reactor Harmonization Working Group of WENRA
RLB	Radiologisches Lagebild Radiological situation report
RLZ-Bund	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
SiAnf	Sicherheitsanforderungen an Kernkraftwerke in Deutschland Safety requirements for nuclear power plants in Germany
SMS	Safety Management System
SRL	Safety Reference Levels
SSCs	Structures, Systems and Components
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
TM	Trockenmasse Dry matter
TPR	Topical Peer Review
TU	Technical University
TÜV	Technischer Überwachungs-Verein Technical Inspection Agency
UVPG	Gesetz über die Umweltverträglichkeitsprüfung Act on the Assessment of Environmental Impacts
vgbe	vgbe energy e.V., formerly “Technische Vereinigung der Großkraftwerksbetreiber”
vgbe-SBS	Sicherheitskulturbewertungssystem des vgbe

	Safety culture assessment system of vgbe
vgbe-ZMA	Zentrale Melde- und Auswertungsstelle des vgbe Central Incident Reporting and Evaluation Office of vgbe
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association
WHO	World Health Organization
WLN	Weiterleitungsnachricht Information notice
ZdB	Zentralstelle des Bundes Federal Central Office

Introduction

The Federal Government regards the Convention on Nuclear Safety (CNS) as a key instrument for maintaining and continuously improving nuclear safety worldwide as well as in Germany. Germany is committed to its international obligations as a Contracting Party, in particular to fulfilling its reporting obligations within the framework of a regular peer review, as laid down nationally in the Act on the Convention on Nuclear Safety of 20 September 1994 (Gesetz zu dem Übereinkommen über nukleare Sicherheit)[1]. This National Report is the report of the Federal Government for the 10th Review Meeting of the Convention on Nuclear Safety, which is scheduled to take place in April 2026.

With the Thirteenth Act Amending the Atomic Energy Act (AtGÄndG), which came into force on 6 August 2011, Germany has enshrined in law the accelerated phase-out of the use of nuclear energy for the commercial generation of electricity (nuclear phase-out) by 31 December 2022 at the latest. The Atomic Energy Act (AtG) was amended on 9 December 2022 with the 19th AtGÄndG against the background of energy supply security to the effect that the continued operation of the three nuclear power plants Emsland (KKE), Isar 2 (KKI 2) and Neckarwestheim II (GKN II), which were still in power operation at that time, is possible in stretch-out operation until 15 April 2023 at the latest. These last three nuclear power plants ceased operation on 15 April 2023, thus finalising the German nuclear phase-out. Ensuring a high level of safety remains a top priority for the Federal Government also in the phase of decommissioning and dismantling of the nuclear power plants taking place now.

The term "nuclear installation" of a Contracting Party is used in this report in accordance with the definition given in Article 2 CNS: *"any land-based civil nuclear power plant under its jurisdiction including such storage, handling and treatment facilities for radioactive materials as are on the same site and are directly related to the operation of the nuclear power plant. Such a plant ceases to be a nuclear installation when all nuclear fuel elements have been removed permanently from the reactor core and have been stored safely in accordance with approved procedures, and a decommissioning programme has been agreed to by the regulatory body".*

Nuclear power plants in power operation and nuclear installations were present in Germany beyond the Joint 8th and 9th Review Meeting of the CNS in March 2023. Germany therefore reports on all articles of the CNS that are mandatory for countries with nuclear installations to fully comply with its obligations under the Convention on Nuclear Safety. The Federal Government also holds the view that the definition of a nuclear installation within the meaning of the CNS should be understood in such a way that a nuclear installation under decommissioning no longer constitutes a nuclear installation within the meaning of the CNS only if it is free of fuel assemblies (FAs) (neither FAs in the reactor core nor in the storage pool).

Due to the completion of the nuclear phase-out in Germany during the review period, not all of the information presented in this report on some articles of the CNS relating to the operation of nuclear installations is relevant for Germany anymore. However, as some of the information was relevant for part of the review period, it is provided. 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 3rd Review Meeting in 2005.

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[1] "Gesetz zu dem Übereinkommen vom 20. September 1994 über nukleare Sicherheit (Gesetz zu dem Übereinkommen über nukleare Sicherheit)" of 7 January 1997; Federal Law Gazette 1997 Part II No 2, published in Bonn on 15 January 1997

This Report of the Federal Government for the 10th Review Meeting of the Convention on Nuclear Safety in April 2026 is an update of the previous report of the Federal Government for the Joint 8th and 9th Review Meeting of the CNS in March 2023 and was prepared jointly by the competent licensing and supervisory authorities of the Federation and the *Länder*[2] as well as by the Technical Association of Large Power Plant Operators vgbe energy e.V. (vgbe, formerly VGB PowerTech e.V.) and by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH.

The report is structured according to the articles of the Convention and follows the provisions of guideline INFCIRC/572/Rev.8 in terms of content. Articles 6 to 19 of the Convention define issues subject to reporting. For each of these articles, this report first explains the relevant laws, ordinances and regulations[3] in separate chapters and then describes how and with which measures the respective requirements of the Convention, in particular the essential safety requirements, are fulfilled by the German nuclear installations.

The Federal Government notes that Germany continues to fulfil all its obligations under the CNS.

This 10th National Report for the 10th Review Meeting in April 2026 was approved by the Cabinet of the Federal Government at its meeting on 24 June 2025.

[2] For the sake of simplicity, the term "competent licensing and supervisory authorities" will be used in the following. For the area of radiation protection, the StrlSchG is the independent formal legal basis in addition to the AtG. As a rule, the licensing and supervisory authority under nuclear law is also the licensing and supervisory authority under radiation protection law.

[3] The report quotes or paraphrases legal texts, non-mandatory regulations and relevant guidelines in many places. In order to reflect this legal context unaltered, it may happen that only one gender is used in some places. However, the report is of course always intended to include all persons regardless of their gender.

Summary

In 1994, the Federal Republic of Germany acceded to the Convention on Nuclear Safety (CNS) as a Contracting Party and since then has been reporting regularly within the framework of the triennial review meetings and the respective preceding national reports. The Federal Government notes that Germany continues to fulfil all its obligations under the Convention on Nuclear Safety as well as the three principles of the Vienna Declaration on Nuclear Safety[4]. Compliance with these principles is set out in the chapters on Articles 6, 14, 17, 18 and 19.

The 19th AtGÄndG extended the operation of the last three nuclear installations generating electricity – Emsland (KKE), Isar 2 (KKI 2) and Neckarwestheim II (GKN II) – beyond the end date for power operation on 31 December 2022 previously provided for under the AtG until 15 April 2023. As a result, additional generation capacity was available in the German electricity grid in the winter of 2022/2023 contributing to secure energy supply and grid security. During this limited period of continued operation, only FAs still present in the respective plant were allowed to be used to generate electricity. This made it clear, that the use of new FAs would not have been permitted. There are currently 33 reactors (including experimental and demonstration reactors) under decommissioning, and the decommissioning of three reactors has been completed with their release from nuclear supervision.

At the Joint 8th and 9th Review Meeting of the CNS in March 2023, Germany received very good appreciation within Country Group 7. The three open challenges of the 7th Review Meeting were considered closed by the Country Group. In the area of safety culture, three “areas of good performance” were recognised at the Joint 8th and 9th Review Meeting: (1) implementation of a web-based tool to exchange information and documents between the various nuclear regulatory authorities and their expert organisations in the field of nuclear safety, (2) availability of a dense network for monitoring environmental radioactivity, and (3) international cooperation to provide support during crisis situations.

During the Joint 8th and 9th Review Meeting, three new challenges were formulated for Germany. These and the current status of each are briefly described below:

<u>Challenge 1:</u> Establish long-term plans to ensure safe and timely decommissioning of German NPPs

Based on the 13th AtGÄndG in 2011, the power operation licences for the Krümmel nuclear power plant and the seven oldest nuclear installations, commissioned up to and including 1980, expired. In 2011, it was further stipulated in the AtG that the authorisation for power operation of the nine nuclear power plants still in power operation at that time will successively expire by 31 December 2022 at the latest (§ 7(1a) sentence 1 AtG). Due to the energy crisis, however, the AtG was amended on 4 December 2022 to the effect that the continued operation of KKE, KKI 2 and GKN II was possible until 15 April 2023 at the latest. These three nuclear power plants ceased operation on 15 April 2023, thus finalising the German phase-out of electricity generation using nuclear energy. Since the end of 2024, all of these plants have been in the process of being decommissioned and dismantled following the granting of a decommissioning and dismantling licence. Decommissioning planning, which contains details of the overall planned measures for dismantling, has already been available when the decommissioning licence was granted. Decommissioning and dismantling and their progress are continuously monitored by the

[4] Vienna Declaration on Nuclear Safety, Vienna, 9 February 2015
https://www.iaea.org/sites/default/files/cns_viennadeclaration090215.pdf

competent licensing and supervisory authorities of the *Länder*. BMUKN regularly exchanges information with the competent licensing and supervisory authorities of the *Länder* on decommissioning and dismantling issues and is kept informed, for example, by means of regular written operator reports.

Challenge 2: Establish a long-term plan to maintain and develop nuclear expertise

In 2020, the Federal Government adopted a strategy for competence building and the development of future talent in the field of nuclear safety. This also took into account the prospective needs of relevant stakeholders (licensing and supervisory authorities of the Federation and the *Länder*, expert organisations, advisory bodies, operating companies, research institutions, universities and industry). These considerations, together with the supplementary needs analyses, set the framework for implementation in the following important areas of action: education and teaching, advanced and continuing training, research and development, knowledge retention, committee work and networks, international networking and cross-border activities as well as career prospects and recognition in society. Implementation is a task for society as a whole, which is supported by the federal ministries in their respective areas of responsibility (see next paragraph). The areas considered by the strategy cover all short-, medium- and long-term national tasks and comprise reactor safety, including nuclear security, decommissioning and dismantling of nuclear installations, nuclear waste management, including storage and disposal, as well as protection against ionising radiation in these areas.

As an example, nuclear safety research at BMUKN is one of the essential pillars. This is implemented in particular through the project funding programme for nuclear safety research of BMUV 2021 to 2025 (now BMUKN) and departmental research on nuclear safety and radiation protection. The focus of the project funding programme is on application-oriented basic research. The departmental research programme develops the scientific basis for the Ministry's departmental tasks, in particular its regulatory responsibilities. Another BMUKN activity derived from the Federal Government's strategy is the establishment and operation of two qualification networks (QV). To this end, an office has been set up for the QV Radiation Protection at the Federal Office for Radiation Protection (BfS) and for the QV Nuclear Safety at the Federal Office for the Safety of Nuclear Waste Management (BASE). Within these networks, synergies in the activities of the institutions involved in competence building and the development of future talent in radiation protection and nuclear safety are leveraged and the joint and overarching cooperation of those involved is fostered.

Challenge 3: Identify the necessary KTA safety standards and transform them into regulations

In two pilot projects, a procedure for transferring the safety standards of the Nuclear Safety Standards Commission (KTA) into nuclear regulations, to be adopted by the Federation and the *Länder*, was tested. These new regulations were to be based on the KTA safety standards and applied to nuclear power plants free from nuclear fuel, research reactors under decommissioning as well as to research reactors in operation. However, the pilot projects have shown that such a transfer is very complex and time-consuming. Completion by 2027, as originally planned, is not considered achievable. Instead, it is planned to set up working groups at the KTA under the Programme and Fundamental Issues Subcommittee, which will either revise the KTA safety standards for the area of application of nuclear power plants without fuel assemblies under decommissioning or will draft application notes for KTA safety standards for this purpose.

Since the preceding National Report of 2022 for the Joint 8th and 9th Review Meeting of the CNS, no anomalies as defined by the International Nuclear and Radiological Event Scale (INES 1) occurred in German nuclear installations.

The high safety level of German nuclear installations had been maintained and improved throughout the entire period of power operation up to the final shutdown of the installations through continual backfitting. The evaluation of the feedback from national and international operating experience as well as monitoring of the state of the art in science and technology were essential means for identifying appropriate backfitting possibilities. For nuclear power plants under decommissioning and research reactors, these processes are being continued in an adapted form. Indications of potential for optimisation were identified sporadically in the current review period. Since the preceding National Report, the Reactor Safety Commission (RSK) has published three statements and one recommendation on important safety-related issues. These are listed under Article 6.

Internationally, Germany is actively involved particularly in the further development of the Safety Standards of the International Atomic Energy Agency (IAEA) and in discussions on safety-related issues within the Western European Nuclear Regulators Association (WENRA). As a member state of the European Atomic Energy Community (Euratom), Germany is also involved, for example, in the implementation of the INSC programme (Instrument for Nuclear Safety Cooperation) to support non-EU countries.

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 nuclear installations

Based on the 13th AtGÄndG in 2011, the power operation licences for the commercial generation of electricity of the Krümmel nuclear power plant (KKK, commissioned in 1984) and the seven oldest nuclear installations, commissioned up to and including 1980, expired. In 2011, it was further stipulated in the AtG that the authorisation for power operation for the commercial generation of electricity of the nine nuclear power plants still in power operation at that time will successively expire by 31 December 2022 at the latest (§ 7(1a) sentence 1 AtG). Due to the Russian war of aggression against Ukraine and the resulting energy crisis, the 19th AtGÄndG permitted power operation of the last three nuclear installations still connected to the grid – KKE, KKI 2 and GKN II – until the end of 15 April 2023. For this limited period of continued operation, only the FAs still present in the respective plant could be used to generate electricity. These three nuclear installations ceased operation on 15 April 2023, thus finalising the German phase-out of electricity generation using nuclear energy. The respective service lives of the three nuclear installations remained significantly below their design lifetimes.

Since the amendment of the AtG in April 2002, the performance of a safety review (SÜ) every ten years has been mandatory for nuclear installations. This obligation can only be waived if the licence holder makes a binding declaration to the competent licensing and supervisory authority confirming that power operation will be terminated no later than three years after the due date of an SÜ. The operators of KKE, KKI 2 and GKN II have made use of this exception so that the last complete SÜs for these nuclear installations were carried out in 2009. In view of the short period of continued operation until 15 April 2023 at the latest, it would have been contrary to the principle of proportionality to require the performance of an SÜ in addition to the ongoing supervision by the regulatory authority. In the course of the short extension, it would also have been technically and objectively impossible to carry out an SÜ. Within the short period of the limited continued operation, it would have been impossible to carry out a final SÜ and to take possible new safety-related findings into account for plant operation. The high safety level of the nuclear installations has been ensured by continuous supervision on the basis of the AtG.

The Reactor Safety Commission (RSK) was requested for advice in order to assess the compatibility of the continued operation of the three affected nuclear installations with nuclear safety. The RSK concluded its deliberations on 11 November 2022 in the form of a statement[5]. In this statement, it made five organisational recommendations. In summary, taking into account the recommendations made, the RSK did not see any safety-related reasons opposing the planned continued operation of KKE, KKI 2 and GKN II until 15 April 2023. Further details can be found in the published statement of the RSK.

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[5] RSK statement “Continued operation of German nuclear power plants until 15 April 2023”, 532nd meeting of the RSK, 11 November 2022 https://www.rskonline.de/sites/default/files/reports/EP-Anlage_RSK532_Weiterbetrieb_hp_en.pdf

The operators provided the core verifications for the new core and carried out the necessary plant-specific measures for this operating phase at some installations (e.g. adjustment of limits). In addition, inspections had to be carried out, the suspension of which had already been tolerated due to the planned shutdown.

The continued operation of the installations also made it necessary to postpone previously planned and defined measures for decommissioning of the installations.

At the time of the CNS Organizational Meeting on 5 September 2024, there were still a total of six nuclear installations in Germany within the meaning of the Convention (→ Figure 6-1, page 22) since there were still FAs in the spent fuel pools. Appendix 1 provides an overview of all permanently shut down and dismantled power and prototype reactors in Germany going beyond the nuclear installations as defined by the Convention.

There is no specific deadline for applying for a decommissioning licence, neither before nor after the cessation of power operation. However, the AtG requires immediate decommissioning and dismantling (§ 7(3) AtG). Applications for decommissioning and dismantling were submitted between 2012 and 2015 for the nuclear installations whose licence for power operation expired in 2011. On average, licensing procedures for decommissioning take four to six years. In the meantime, applications for decommissioning and dismantling have been submitted for all nuclear installations in Germany and the corresponding licences have been granted.

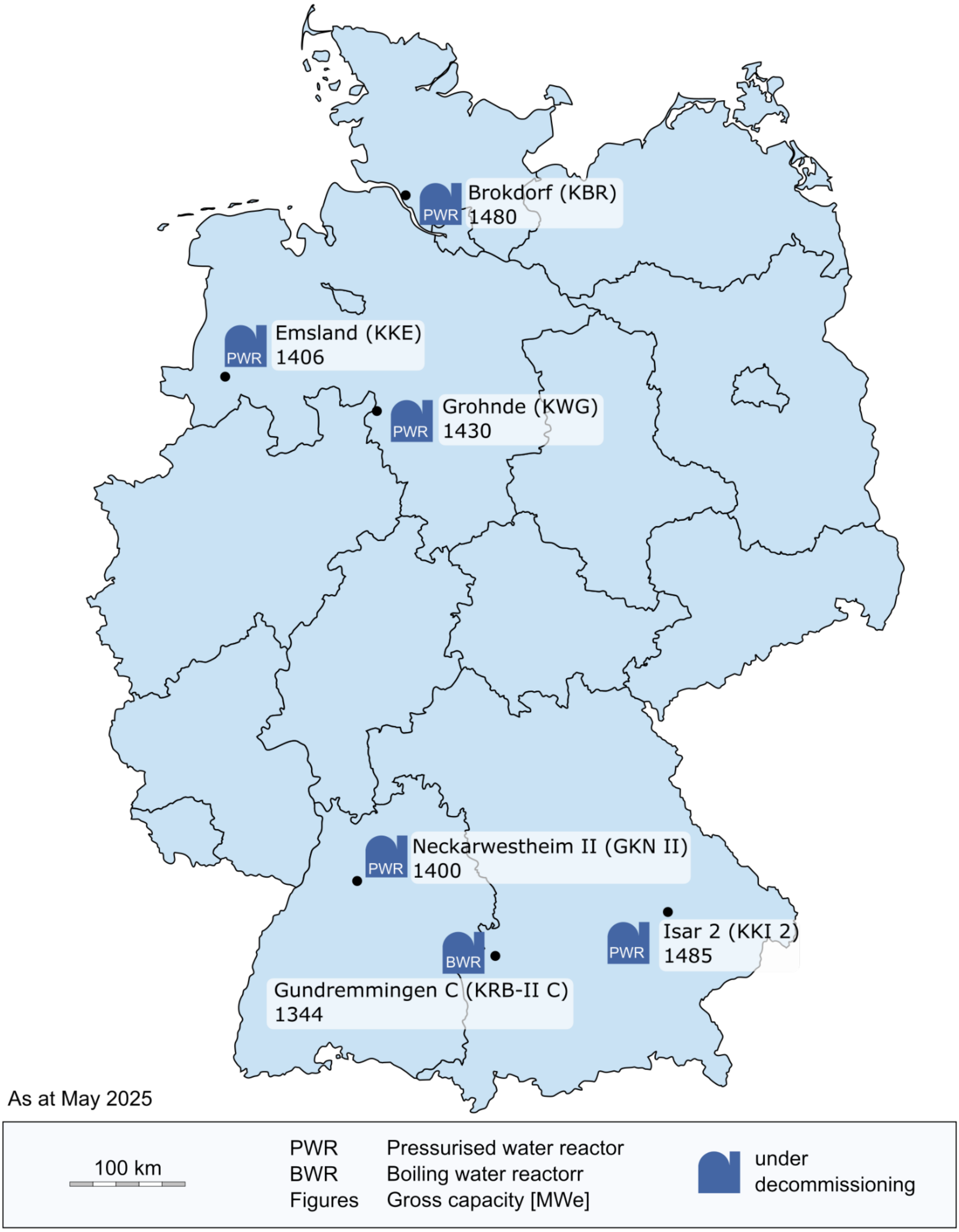

Figure 6-1 Nuclear installations as defined by the Convention for electricity generation in Germany

When examining the application for a decommissioning licence, the competent authority checks whether the conditions for granting the licence are fulfilled. This applies both to the aspects of residual operation and to the specific aspects of dismantling. Within the scope of the licence application, information is provided on the planned decommissioning measures, which essentially comprise the following:

- scope of the dismantling projects,
- description of the affected SSCs (Structures, Systems and Components),
- condition of the installation at the start of dismantling,
- which rooms are to be used,
- radiological situation,
- dismantling techniques to be used,
- utilisation of infrastructure,
- interaction with residual operation,
- necessary structures,
- radiation protection,
- fire protection, and
- estimation of waste generation.

Within the framework of the licensing procedure, documents must be submitted by the licence holder and evaluated by the competent authority. Often, additional information is requested by the competent authority during the evaluation. The time for the preparation of the documents by the applicant, for public participation and the time for the evaluation by the competent authority and its authorised expert determine the duration of the licensing procedure.

According to their design at the time of construction, the German nuclear installations for commercial electricity generation can be classified according to four construction lines for pressurised water reactors (PWRs) and two construction lines for boiling water reactors (BWRs). Appendix 3 (→ page 195) contains a compilation of technical details on the nuclear installations of the various construction lines last operated.

Availability of the nuclear installations

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 %** (available operating time/ calendar time)	**Energy availability in %** (possible energy generation/ nominal generation)	**Energy utilisation in %** (actual energy generation/ nominal generation)
2023	87.8	71.4	65.7
2022	95.5	94.0	89.8
2021	95.9	95.6	92.1
2020	90.6	88.6	85.5
2019	90.8	88.9	85.2
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

Use of mixed-oxide fuel

Since 1 July 2005, the transfer of spent fuel from nuclear installations for reprocessing has been prohibited. 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 all separated plutonium has been fully completed by reuse during the lifetime of German nuclear installations.

Modification licences

From 2022 to 2024, no more modification licences were granted for power operation.

Post-operational phase

After the authorisation for power operation has expired, the nuclear installations will go into the post-operational phase. In terms of licensing, the post-operational phase still falls under the operating licence. Once the decommissioning licence has been granted and utilised, the nuclear installations are decommissioned. Depending on the planned and applied-for decommissioning procedure, operating processes that have to continue unchanged, e.g. wet cooling of irradiated FAs, may not be covered by the decommissioning application. In this case, the operating licence, including the associated safety demonstrations, continues to apply in parallel to the decommissioning licence for these activities until these processes are completed.

Research reactors

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

In Germany, six research reactors are currently (as at May 2025) operated with thermal outputs between 100 mW and 20 MW (→ Appendix 2-1a, page 190). The licence holders of the research reactors are public or state-sponsored universities and research centres. Two of these reactors with thermal outputs between 100 kW and 20 MW are operated primarily as neutron sources for research. 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, page 190) and six research reactors are under decommissioning and being dismantled (→ Appendix 2-2, page 191).

For the licensing and supervision of research reactors, the safety regulations for power reactors are applied, among others, by analogy. This was specified in the Guideline for the application of the nuclear rules and regulations for nuclear power plants to research reactors by means of a graded approach of 10 October 2023. Depending on the risk potential of the respective research reactor, a multi-level approach is applied by the competent licensing and supervisory authorities of the *Länder* (→ Figure 6-2, page 26).

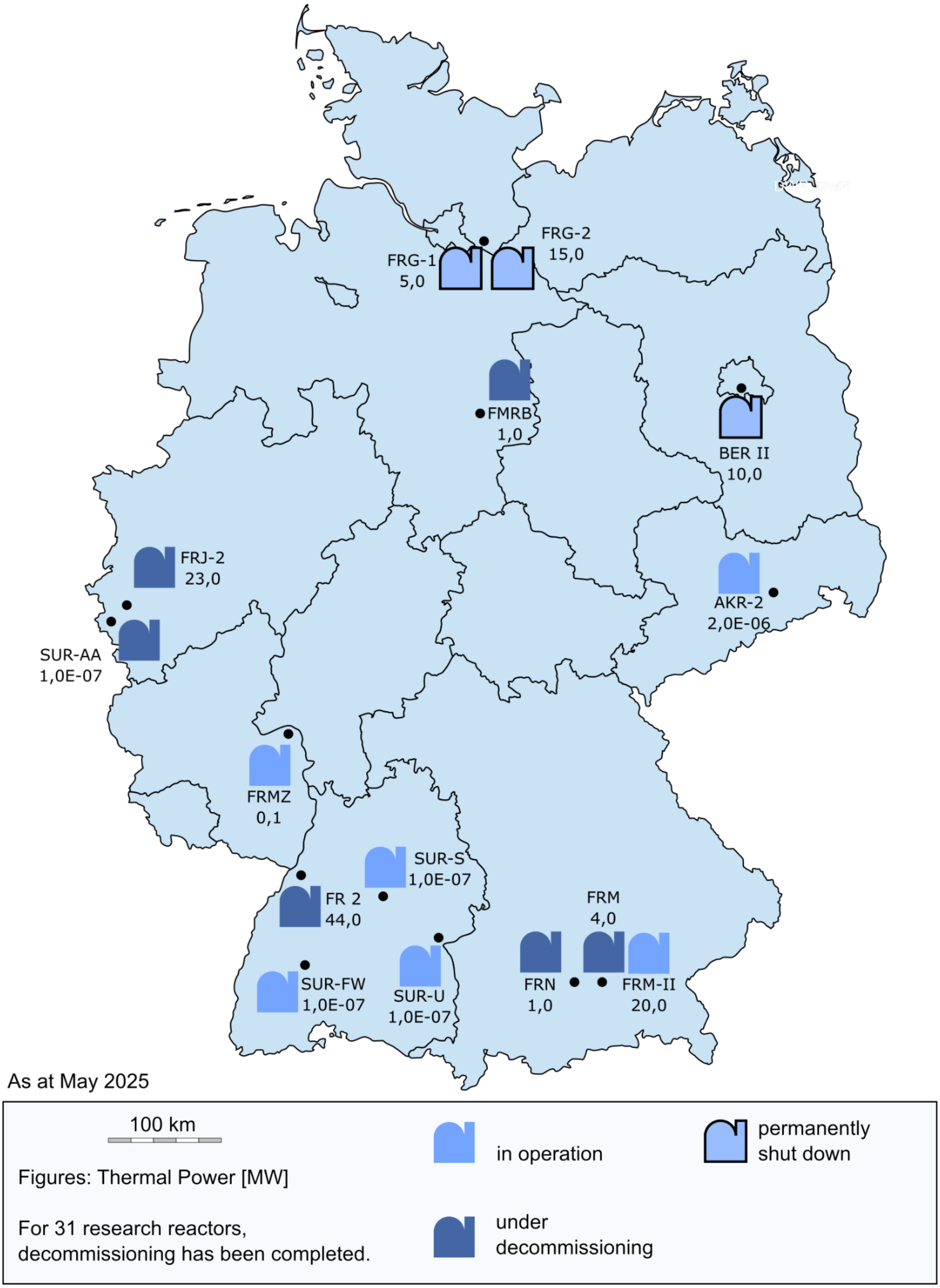

Figure 6-2 Research reactors in Germany

Other nuclear installations

To complete the picture of nuclear energy use 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, on which Germany last reported within the framework of the National Report of the 8th Review Meeting in March 2025[6].

The thorium high-temperature reactor is in "safe enclosure" status (→ Appendix 1-2, page 185). The nuclear installations "Heißdampfreaktor Großwelzheim", "Kernkraftwerk Niederaichbach" and the "Versuchsatomkraftwerk Kahl" have already been completely dismantled and are thus released from nuclear and radiation protection supervision (→ Appendix 1-2, page 189).

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 spent fuel storage facility (BZA), Gorleben spent fuel storage facility (BZG) and the storage facility "Zwischenlager Nord" in Rubenow, in the cask storage facility of the "Arbeitsgemeinschaft Versuchsreaktor (AVR) Jülich") and in storage facilities at the sites of the nuclear installations. The storage licences are issued by BASE. 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 until 1991 and 1994 until 1998, low- and intermediate-level radioactive waste was disposed of in the Morsleben repositor for radioactive waste (ERAM). In April 2017, the Federal company for radioactive waste disposal (BGE) assumed operator responsibility for ERAM. It thus also assumed the role of the applicant in the licensing procedure for closure. Supervision of ERAM under nuclear and radiation protection law is exercised by BASE.

In the period from 1967 until 1978, low- and intermediate-level radioactive waste was emplaced in the Asse II mine. In 2013, the retrieval of the radioactive waste and subsequent decommissioning of the facility was established by law. On 25 April 2017, the operatorship of the BfS was transferred to BGE, which thus is responsible for the retrieval of the waste emplaced. Supervision of the Asse II mine under nuclear and radiation protection law is carried out by BASE.

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. BGE expects the conversion to be completed by the end of 2029. The licence holder of the Konrad repository is BGE. Nuclear and radiation protection supervision is exercised by BASE.

A site for a disposal facility for high-level radioactive waste is to be found in Germany. The individual procedural steps are regulated by the Site Selection Act (StandAG), which came into force in 2017. The site selection procedure is divided into three successive phases:

- Phase I: Identification of subareas (Step 1) and proposal for siting regions on the basis of existing data (Step 2)

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[6] Report of the Federal Government for the Eighth Review Meeting in May 2021 on the fulfilment of the obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, BMUV, August 2024, https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/jc_8_bericht_deutschland_atomenergie_en_bf.pdf

- Phase II: Surface exploration
- Phase III: Underground exploration

The procedure is currently in Step 2 of Phase I, in which the determination of siting regions for surface exploration pursuant to § 14 StandAG is carried out on the basis of the previously identified subareas and the consultation results of the Subareas Conference. Due to the orientation as a science-based, transparent and learning process – which provides for comprehensive public participation and is characterised by the protection goal of identifying the site with the best possible safety for a period of one million years – it has become apparent that the target year of 2031 for the siting decision, as provided for by law, cannot be met.

BASE exercises regulatory supervision over the site selection procedure for a disposal facility for high-level radioactive waste and involves the public in its capacity as the body responsible for public participation.

BGE acts as the project implementer, which aims to finalise the determination of siting regions for surface exploration by the end of 2027. The main ongoing work of BGE in Step 2 of Phase I serves to narrow down the areas to the siting regions. Currently, priority is given to categorise areas step by step into categories D to A, which are announced annually. Category A areas are the most favourable from a safety perspective. At the end of 2024, BGE published work statuses in the form of site categorisations in Category D (unsuitable) and C (less suitable). The siting region proposal expected by the end of 2027 will also propose the programmes for the surface geoscientific exploration of the siting regions in Phase II.

The site selection procedure involves intensive public participation. In 2020 and 2021, a Subareas Conference[7] was held and in subsequent years the "Forum Endlagersuche" *(forum on the search for a repository)* also to accompany the work steps of BGE and making them comprehensible and transparent. Citizens and interested experts (representatives of local authorities, civil society organisations and the scientific community) can participate in the site selection procedure. After the publication of the siting region proposal, the participation formats of regional conferences and the Council of the Regions Conference will continue to enable comprehensive public participation.

Overview of important safety issues including selected events

Between the editorial deadline for the 9th National Report for the Joint 8th and 9th Review Meeting of the CNS and the editorial deadline for the National Report for the 10th Review Meeting (May 2022 to May 2025), no events occurred at German nuclear installations that were classified as events according to INES 1 or higher.

In 2023, during the removal of a CASTOR® cask from the cask loading pool, a component of the cask's lifting lug was damaged due to an improperly executed handling step. A safety bolt had not been inserted far enough and not secured in the end position. However, the possibility of the cask dropping down was not to be assumed. In order to prevent recurrence, the staff responsible for handling were trained accordingly. In addition, an adjustment was made to the cask-specific work process procedure. For this event, information notice (WLN) 2024/01 was drawn up.

In the period from 2022 to 2024, deficiencies in the preloading documentation of various CASTOR® loading campaigns were reported in four other event reports. In one case, the physical modelling of individual FAs was based on uranium/gadolinium instead of pure uranium as material. This resulted in a slightly higher burn-up and a slightly higher decay heat output for the affected and already loaded FAs. The modelling was repeated correctly and it was confirmed that all safety-relevant limits of the loading configurations were safely adhered to. In two other cases, the so-called utilisation factor was not correctly determined within the framework of the preloading documentation. The utilisation factor is used to compare the maximum power peaking of the decay power for a fuel assembly to be loaded

[7] Sub-areas conference; https://www.endlagersuche-infoplattform.de/webs/Endlagersuche/EN/sub-areas-conference/sub-areas-conference_node.html

with the permissible specifications of the thermal verification. The re-evaluations of the corresponding loading campaigns carried out until then showed that the thermal boundary conditions had been met. Both events are due to incorrect IT-related implementation of amended licence conditions. Another event is due to the swapping of input files of two FAs that are required for nuclear physics calculations. As a result, the calculated use-specific data for the two FAs no longer corresponded to the actual operating history. A recalculation of the use-specific data was carried out. The event did not lead to any safety-relevant deviation in the loading configuration for the corresponding cask.

The protection goals for the FAs and casks were not violated in any of the cases mentioned. As part of the investigation into these events, optimisations were made in the organisational area and in quality management.

In recent years, several events have been reported from permanently shut-down German nuclear installations in which dismantling activities were performed mistakenly on components not intended for dismantling. For example, sawing started on a piping not yet cleared for dismantling, a pipeline still in operation was incorrectly cut, a drain funnel with part of the associated manifold line was mistakenly dismantled and disposed of, and a cut was made on the sealed concrete pit drainage line not yet taken out of service. The analyses of the events showed deficiencies and potential for improvement, particularly with regard to organisational precautions. In particular, unclear or missing marking of the components taken out of service is a contributing factor here. These deficiencies led, for example, to personnel making incorrect assumptions regarding the components to be dismantled. Other factors contributing to the events included faulty work execution (questioning attitude in case of ambiguous circumstances) and deviations from specified procedures. The faulty dismantling of plant components not cleared for dismantling can potentially affect all plant components with passive or active safety functions still required. This can have safety-related or radiological consequences. The events therefore have potential safety significance. Due to the applicability of the events to other nuclear installations undergoing dismantling in Germany and abroad, GRS has published the information notice WLN 2023/04 and submitted a report to the IRS of the IAEA (IRS Number 9246).

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

Since the editorial deadline for the 9th National Report for the Joint 8th and 9th Review Meeting of the CNS in May 2022, the RSK has published a total of three statements and one recommendation on important safety issues relating to nuclear installations in Germany:

Statements:

- Continued operation of German nuclear power plants until 15 April 2023 (11 November 2022)[8]
- Assessment of the technical contribution of the possibly expanded THAI experimantal facility with regard to the safety assessment of research and power reactors as well as competence building and development of future talent in the field of nuclear safety (22 February 2023)[9]
- Requirements for the cooling of the FAs in the spent fuel pool during residual operation (revised version of 13 December 2023)[10]

Recommendation:

- Planning and inspection of work during residual operation (13 December 2023)[11]

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8 RSK statement “Continued operation of German nuclear power plants until 15 April 2023”, 532nd meeting of the RSK, 11 November 2022; https://www.rskonline.de/sites/default/files/reports/EP-Anlage_RSK532_Weiterbetrieb_hp_en.pdf

9 RSK statement “Assessment of the technical contribution of the possibly expanded THAI experimental facility with regard to the safety assessment of research and power reactors as well as competence building and development of future talent for nuclear safety”, 534th meeting of the RSK, 22 February 2023; https://www.rskonline.de/sites/default/files/reports/EP-Anlage_RSK534-hp-EN.pdf

10 RSK statement “Requirements for the cooling of the fuel assemblies in the spent fuel pool during residual operation (revised version of 13 December 2023)”, 539th meeting of the RSK, 13th December 2023; https://www.rskonline.de/sites/default/files/reports/EP-Anlage1_RSK539_hp_en.pdf

11 RSK recommendation “Planning and inspection of work during residual operation”, 539th meeting of the RSK, 13 December 2023; https://www.rskonline.de/sites/default/files/reports/EP-Anlage2_RSK539_hp_en.pdf

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 19(vii), page 177). Once the FAs have been removed from a nuclear installation, the radiological hazard potential decreases significantly.

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. Behaviour during safety-relevant activities (e.g. maintenance orders) is practised under real conditions on the training paths.

Research for the safety of nuclear installations

Germany phased out the use of nuclear energy for the commercial generation of electricity on 15 April 2023. The risk assessment on which this decision by the legislator is based is also taken into account in the funding of nuclear safety research. In the field of reactor safety research, technical and scientific issues relating to the operation of German research reactors and the decommissioning and dismantling of German nuclear power plants and research reactors are of great importance. In addition, the safe operation of nuclear installations abroad is also in Germany's direct safety interest as the consequences of nuclear accidents and incidents can have cross-border effects. For this reason, the Federal Republic of Germany continues to monitor international developments in reactor safety (including the assessment of the safety of new reactor types) and in nuclear waste management and is actively involved in the international discussion of nuclear safety issues and the further development of the state of the art in science and technology. In particular, Germany participates in exclusively safety-oriented multinational research projects under the auspices of the OECD/NEA (Organisation for Economic Co-operation and Development/Nuclear Energy Agency) and organises such projects itselfs. However, funding for the use of nuclear energy for the commercial generation of electricity is out of the question.

The project funding programme of BMUV (now BMUKN) for safety research for nuclear facilities 2021 to 2025 funds research and development projects on reactor safety research, research on extended storage and treatment of high-level radioactive waste, repository research as well as research on cross-cutting issues in these areas. BMUKN's departmental research, on the other hand, is focussed on supporting ministerial tasks and regulatory work in the fields of nuclear safety and radiation protection through specific task-related research, investigations and development work.

In addition the Federal Ministry of Research, Technology and Space (BMFTR) funds projects on the topics of safety and waste management research as well as radiation research within the framework of the guideline on the funding of grants under the 7th Energy Research Programme of the Federal Government in nuclear safety research and radiation research. BMFTR's guideline for the funding of projects funded under the FORKA (Research for the dismantling of nuclear facilities) concept is used to fund topics relating to the decommissioning and dismantling of nuclear installations. BMFTR is also responsible for the institutional financing of the activities of the Helmholtz-Gemeinschaft (HGF) in the field of nuclear safety research within the Helmholtz programme “NUSAFE”.

The research work funded by the Federal Government in the field of reactor safety research includes 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 severe 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 actions 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 projects are available to the supervisory authorities and their authorised experts for analyses of the safety of nuclear installations.

In general, the *Länder* do not have any research programmes dedicated to nuclear safety. As part of their responsibilities, they fund the general costs of universities.

Research and development in the field of nuclear safety also continues to be given high priority by the licence holders of nuclear installations via the technical association of energy plant operators vgbe energy e.V. Due to the completed phase-out of the use of nuclear energy for the commercial generation of electricity in 2023, the licence holders are focusing their efforts on the residual operation of the shutdown plants as well as their decommissioning and dismantling. There are currently 20 to 25 projects. In addition to specially financed services provided by the association, the projects focus on the following topics:

- investigations on decommissioning and dismantling,
- assessment of events,
- functional integrity of electrical and control systems used,
- operation of databases, and
- Codes of Rules and legal questions.

Activities of the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN)

In fulfilling its statutory tasks for the safe use of nuclear energy, BMUKN has to clarify questions of fundamental importance for the safety of nuclear installations (→ Article 8, page 54).

BMUKN keeps continuously up to date with the developments in the field of nuclear safety by taking an active part – partly with the support of subordinate authorities (BASE, BfS) and also from the *Land* authorities – 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. BMUKN also requests its advisory commissions RSK, ESK and SSK (Commission on Radiological Protection) (→ Article 8, page 67) 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 BMUKN and carries out research projects on the safety of nuclear installations on behalf of BMUKN. GRS evaluates events that have occurred in German as well as foreign nuclear installations with regard to their safety significance and applicability to other German installations and prepares recommendations in the form of a WLN.

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”. Regarding the principles, this is reported on in Articles 14, 17, 18 and 19.

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*[12] 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.

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

Constitutional framework

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 Constitution of the Federal Republic of Germany, the Basic Law (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 safety of nuclear installations and radiation protection was thus transferred to BMUKN. The GG has assigned the legislative power for the peaceful use of nuclear energy to the Federation. As part of the Federal Government, BMUKN is involved in legislation, in particular by drafting legislation, while the *Länder* implement the AtG and the Act on the Protection Against the Harmful Effect of Ionising Radiation (StrlSchG) on behalf of the Federation (federal executive administration).

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[12] For the sake of simplicity, the term "competent licensing and supervisory authorities" will be used in the following. For the area of radiation protection, the Radiation Protection Act is an independent formal legal basis additional to the Atomic Energy Act. As a rule, the licensing and supervisory authority under nuclear law is also the licensing and supervisory authority under radiation protection law.

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 (Euratom) and the European Union (EU)

In Germany, legislation and administrative work must take into account any binding requirement from regulations of 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 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. This Directive 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, the StrlSchG was passed.

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 competent 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 AtGÄndG[13].

With Directive 2014/87/Euratom of 8 July 2014, Directive 2009/71/Euratom was amended. By this amendment, for the first time, general technical requirements for nuclear safety in Europe were 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 licensing and supervisory authorities 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 way, a continuous system of mutual learning from each other is to be initiated. Directive 2014/87/Euratom was transposed into national law with the entry into force of the 15th AtGÄndG on 9 June 2017.

[13] Twelfth Act Amending the Atomic Energy Act, 8 December 2010; https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&bk=Bundesanzeiger_BGBl&start=//*%255B@attr_id=%2527bgbl110s1817.pdf%2527%255D#/switch/tocPane?_ts=1752664458772

7 (2i) Nuclear legal and regulatory framework

National nuclear legal and regulatory framework

The “Manual on Reactor Safety and Radiation Protection” [14] 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.

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

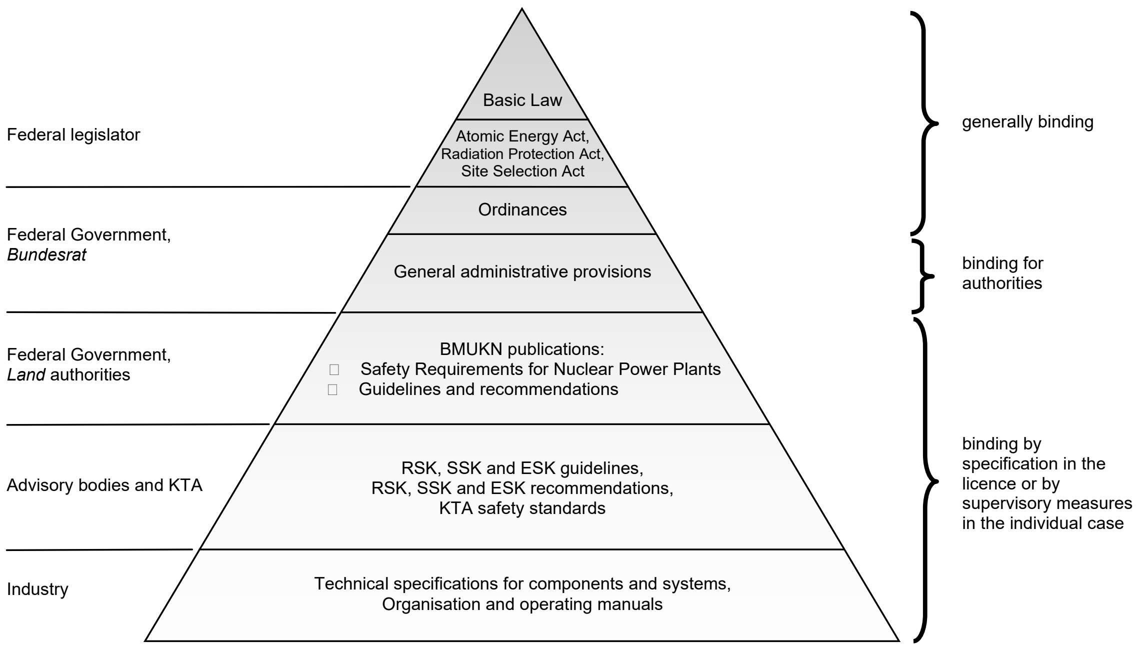

Figure 7-1 National regulatory pyramid

[14] Manual on Reactor Safety and Radiation Protection, BASE; https://www.base.bund.de/de/service/gesetze-regelungen/handbuch-reaktorsicherheit-strahlenschutz/rsh-handbuch-reaktorsicherheit-strahlenschutz_inhalt.html

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.

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

Atomic Energy Act (AtG)

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,
- to prevent danger to the internal or external security of the Federal Republic of Germany from the use of nuclear energy, and
- 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 passed the 13th AtGÄndG to phase out the commercial use of nuclear energy, beginning at the earliest possible date by 31 December 2022 at the latest, following the reactor accident in Fukushima. Due to the Russian war of aggression against Ukraine and the resulting energy crisis, the 19th AtGÄndG permitted power operation of the last three nuclear installations still connected to the grid – KKE, KKI 2 and GKN II – until the end of 15 April 2023. For this limited period of continued operation, only the FAs still present in the respective plant could be used to generate electricity.

The 19th AtGÄndG came into force on 4 December 2022. This temporary continued operation meant that additional generation capacity was available in the German electricity grid in the winter of 2022/2023 to make a positive contribution to the power balance and grid security.

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 and also its decommissioning. Further licensing regulations are contained in § 4 AtG for the transport of nuclear fuel, in § 6 AtG for the storage of nuclear fuel, in § 9 AtG for the processing, treatment and other utilisation of nuclear fuel outside of facilities requiring a licence, and in § 9a AtG for the utilisation of radioactive residues and the disposal of radioactive waste.

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 as well as the authorisations to issue statutory instruments have been in force since 1 October 2017. The StrlSchG regulates

- 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.

Acts on the establishment of nuclear authorities

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 competent 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 today’s BASE. With this Act, BASE 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, BASE 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 (StrlSchV) – which is based in particular on authorisations to issue ordinances under the StrlSchG – entered into force. The new StrlSchV contains provisions which supplement and concretise the provisions of the StrlSchG. The StrlSchG and the StrlSchV together ensure comprehensive protection against the harmful effects of ionising radiation.

The Fourth Ordinance Amending the Radiation Protection Ordinance of 10 January 2024 (BGBl. 2024 I No. 8) made a number of changes, primarily related to enforcement. These include the introduction of safety assessments to be performed by authorised experts for laser systems requiring notification and enabling the recognition of courses to acquire or update the required technical qualification in radiation protection with exclusively online courses. Further minor changes were made by the Ordinance Amending the Wastewater Ordinance and Amending the Radiation Protection Ordinance of 17 April 2024 (BGBl. 2024 I No. 132). Furthermore, the Medical Research Act of 23 October 2024 (BGBl. 2024 I No. 324) requires the radiation protection executive to ensure that the sum of the study-related effective doses from indicated applications to sick minors as part of a research project does not exceed the limit of 6 mSV. The latter amendment will come into force on 1 July 2025.

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

Brief description on the legislative content	
AtAV	**Nuclear Waste Shipment Ordinance** Shipment of radioactive waste into or out of the territory of the Federal Republic of Germany
AtDeckV	**Nuclear Financial Security Ordinance** Financial security according to the AtG
AtEV	**Nuclear Waste Management Ordinance** Ordinance on requirements and procedures for the management of radioactive waste: generation, whereabouts, collection, treatment, packaging, delivery/receipt and storage of radioactive waste
AtSKostV	**Cost Ordinance under the Atomic Energy Act and the Radiation Protection Act** Charging of costs in procedures under nuclear and radiation protection law
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
AtVfV	**Nuclear Licensing Procedure Ordinance** Application documents (one safety analysis report), public participation, safety specifications (operational limits and conditions of safe operation), procedures and criteria for major modifications
AtZüV	**Nuclear Trustworthiness Verification Ordinance** Verification of trustworthiness of persons to protect against diversion or major release of radioactive material
EndlagerVlV	**Repository Prepayment Ordinance** Advance payments for the construction of federal facilities for the long-term engineered storage and disposal of radioactive waste
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

Brief description on the legislative content	
KIV	**Ordinance Concerning Potassium Iodide Tablets** Provision and distribution of medicine containing potassium iodide as thyroid blocker in case of radiological events
NDWV	**Emergency Dose Level Ordinance** Definition of dose levels for early emergency response measures
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

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 and radiation protection are listed in the Manual on Reactor Safety and Radiation Protection.

Documents provisionally considered as federal emergency plans

According to §§ 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 BMUKN (→ Article 16, page 129). 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 of general administrative provisions with the consent of the Bundesrat. For the time being, various existing documents pursuant to Annex 4 StrlSchG and further *Land*-specific documents function as binding provisional emergency plans of the Federation (§ 97(5) StrlSchG).

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 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 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 BMUKN

After having consulted the competent licensing and supervisory authorities, BMUKN publishes regulatory guidelines in the form of requirements, guidelines, criteria and recommendations. In general, these are regulations passed in consensus with the competent supreme *Land* authorities, some of which also assume the task of licensing and supervisory authority, on the uniform application of the nuclear and radiation protection law.

BMUKN publications describe the view of the supreme federal authority responsible for the nuclear safety of nuclear installations and for radiation protection and, if the decisions were taken in the *Länder* Committee for Nuclear Energy (LAA), also the view of the competent *Land* authority on general issues (of nuclear safety, radiation protection, emergency preparedness) and administrative practice and serve as orientation for the competent licensing and supervisory authorities of the *Länder* in the execution of the nuclear and radiation protection law. They are referred to by the competent 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 by orders of the nuclear supervisory body.

The most important substatutory nuclear regulations are the “Safety Requirements for Nuclear Power Plants” (SiAnf), 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 licences. The last update of the SiAnf was published on 25 February 2022. Where necessary for safety reasons, the SiAnf are also to be applied when nuclear installations have finally ceased power operation. In the post-operational phase, i.e. in the phase after final cessation of power operation and before the decommissioning licence is granted, some requirements can be modified within the framework of supervisory procedures of the *Länder* (e.g. scope and intervals of in-service inspections) and some systems that are only necessary for power operation can be taken out of service permanently. Examples of such systems are the reactor SCRAM system, the pressurising system, the extra borating system, systems from the secondary circuit in PWRs and electrical systems for power generation, such as the generator.

Research reactors are generally subject to the same licensing and supervisory requirements as nuclear installations, although they have a significantly lower hazard potential in comparison. In order to describe the appropriate application of the regulations developed for nuclear installations to research reactors in operation and post-operation, the guideline on the application of the nuclear regulations for nuclear power plants to research reactors using a graded approach was published in 2023.

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 severe accidents,
- measures regarding disaster control in the vicinity of nuclear installations,
- measures against malicious acts,
- 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 SÜ for nuclear power plants,

- 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,
- personnel qualification,
- periodic safety review for research reactors, and
- analogous application of the nuclear regulations for nuclear power plants to research reactors.

Other regulations on the safety of nuclear installations

KTA safety standards

The safety standards of the Nuclear Safety Standards Commission (KTA) specify, among other things, the safety requirements of the general regulations (SiAnf and their "Interpretations") and put them into concrete terms.

The KTA is formed at BMUKN. 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 five 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 GG,
- consultants and consultancy organisations, and
- other authorities, organisations and bodies concerned with nuclear technology.

The KTA is governed by an Executive Committee consisting of four members. The groups of the manufacturers and builders, the licence holders, the authorities and the authorised experts nominate one member and one deputy each for a term of four years. 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 BASE. This office is led by a managing director in accordance with the technical instructions given by the KTA Executive Committee. When the KTA was founded in 1972, the KTA Secretariat was established at GRS. In 1991, with the foundation of BfS, the KTA Secretariat was transferred from GRS (1972 to 1991) to BfS (1991 to 2017). With the foundation of BASE in 2016 (then BfE), the KTA Secretariat became a part of BASE in 2017.

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 sixths 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 safety standards of the KTA 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. The safety standards of the KTA relate, among other things, 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.

Historically, the safety standards of the KTA 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. Since 2010, findings from the KTA have also been flowing back into the ASME Code due to a bilateral cooperation between the KTA and ASME.

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 safety standards of the KTA also includes the field of ageing, which is internationally treated as a separate issue today. There are also separate safety standards of the KTA for management systems and ageing management.

The body of KTA safety standards currently comprises 97 rules and regulations. In 2022, 88 safety standards of the KTA were reviewed for their continued validity or need for amendment in order to ensure that the required safety standards of the KTA continue to be available for decommissioning of nuclear power plants as well as for other users of safety standards of the KTA (repositories, storage facilities, research reactors, etc.). Nine safety standards of the KTA are no longer subject to regular review, as they have been put on hold by the KTA.

Most recently, the new version of safety standard KTA 1404 (version 2023-12) “Documentation During the Construction and Operation of Nuclear Power Plants” was published on 17 January 2024. With safety standard KTA 2201.2 “Design of Nuclear Power Plants against Seismic Events; Part 2: Subsoil”, one safety standard is currently under revision. On 6 December 2024, the corresponding draft safety standard in the version 2024-12 was adopted by the KTA and published on 17 January 2025.

In two pilot projects, a procedure for transferring the KTA safety standards into nuclear regulations, to be adopted by the Federation and the *Länder*, was tested. These new regulations were to be based on the KTA safety standards and applied to nuclear power plants free from nuclear fuel, research reactors under decommissioning as well as to research reactors in operation. The pilot projects have shown that such transfer is very complex and time-consuming. Completion by 2027 is not considered achievable.

Instead, it is planned to set up working groups at the KTA under the Programme and Fundamental Issues Subcommittee, which will either revise the KTA safety standards for the area of application of nuclear power plants without fuel assemblies under decommissioning or will draft application notes for KTA safety standards for this purpose. The revised safety standards will then be published as decommissioning-specific safety standards and the original safety standards will be suspended.

The KTA safety standards are processed according to a prioritisation list. Some standards are also categorised as still fully applicable. In a future review of the standards to ensure that they are up to date, the standards will only be updated with regard to the area of application, i.e. the dismantling of nuclear power plants without FAs. In the case of KTA safety standards for which application notes have been drawn up, the update will be realised using the application notes.

The KTA has published a statemen[15] on this.

The development and maintenance of regulations for the operation of research reactors is still under discussion.

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

BMUKN requests its commissions RSK, ESK and SSK (→ Article 8, page 67) 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 competent licensing and supervisory authorities of the *Länder*, authorised 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 BMUKN. The competent licensing and supervisory authorities of the *Länder* review the decisions (recommendations and statements) of the commissions on their own responsibility in the nuclear and radiation protection licensing and supervisory procedures, in particular with regard to installation-specific relevance. They decide whether, and if so, what action is required in any given case and initiate any necessary measures. The competent licensing and supervisory authorities of the *Länder* report to BMUKN on request on the status of implementation. BMUKN will take overarching findings into account when updating the nuclear rules and regulations.

Conventional technical standards

For the construction and operation of nuclear installations, conventional technical standards apply as a supplement.

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.

In the area of standardisation, the national standardisation of the German Institute for Standardization (DIN) and the international standardisation according to ISO (International Organization for Standardisation) and IEC (International Electrotechnical Commission) are to be mentioned here in particular.

[15] KTA: https://www.kta-gs.de/d/Info_Weiterarbeit_KTA-2025_02_28.pdf

Updating nuclear rules and regulations

In Germany, the internal regulations on the periodicity of the revision of rules and guidelines are set out in the Handbook on Cooperation between the Federation and the *Länder* in Nuclear Law.[16]

In addition to a description of the supervisory and licensing processes for cooperation between the Federation and the *Länder* in nuclear law procedures, the following processes for revising regulations and guidelines are described in the supervision manual:

- Process 16: refers to the KTA safety standards, which should be reviewed at least every five years.
- Process 17: refers to the further development of the international rules and regulations, in particular the IAEA Safety Standards, and their implementation at the national level in order to keep the national regulations up to date with the state of the art in science and technology.
- Process 22: refers to the substatutory regulations which should be reviewed every five years or when necessary changes are identified, e.g. based on monitoring the results of the work of relevant (inter)national, multilateral and bilateral bodies and institutions, the results of government-funded research programmes, international regulations, research and development projects.

Additional processes in the supervision manual cover the topics of research reactors and decommissioning. A separate part of the manual consisting of processes dedicated to the area of “waste management” is also at an advanced stage of completion. The periodicity of the review of the rules and guidelines on these topics is also documented in the corresponding processes.

Based on the guideline for the performance of periodic safety reviews for nuclear power plants, a guideline for the performance of periodic safety reviews for research reactors has been drawn up as a result of the IRRS Mission 2019.

Within the framework of the Follow-up Mission 2023, the suggestion was made that BMUV (now BMUKN) should develop regulations together with the *Länder* to give interested parties (e.g. the public) the opportunity to comment before decommissioning is completed (release from the scope of the AtG). A corresponding amendment to the supervision manual is currently being prepared.

As part of the state of the art, the WENRA safety reference levels (SRLs) are taken into account in the revision processes of the German nuclear regulations. A detailed analysis of implementation was carried out back in 2011 when Germany developed its new SiAnf. Most of the SRLs are implemented in it, others in other BMUKN publications, RSK recommendations and KTA safety standards. In 2022, Germany carried out a self-assessment of the updated WENRA SRLs (2020 revision) on issues C (management system), I (ageing management), SV (internal hazards) and TU (external hazards). The results of the self-assessment are currently being discussed within the framework of WENRA.

Development of international rules and regulations

With the competent 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 Safety Standards and Security Guidance. Furthermore, staff members of BMUKN, BASE and BfS are involved as members of all standard committees of the IAEA:

- CSS (Commission on Safety Standards)
- NUSSC (Nuclear Safety Standards Committee)

[16] “Handbuch über die Zusammenarbeit zwischen Bund und Ländern” (June 2023) https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/bund_laender_aufsichtshandbuch_atomrecht_bf.pdf

- EPreSSC (Emergency Preparedness Safety Standard Committee)
- RASSC (Radiation Safety Standards Committee)
- TRANSSC (Transport Safety Standards Committee)
- WASSC (Waste Safety Standards Committee)
- NSGC (Nuclear Security Guidance Committee)

Germany is thus making an active contribution to the international harmonisation and further development of safety requirements. Since 2006, the IAEA's rule-making activities have been summarised in an annual BMUKN report provided to the competent licensing and supervisory authorities of the *Länder* and their authorised experts. Before updating a specific German ordinance or guideline, a gap analysis is carried out with the current safety standards in order to identify deviations and develop proposals for improving the German legal framework.

In addition, Germany, as a member of WENRA and its working groups, is actively involved in the WENRA “Safety Reference Levels” and “Safety Objectives” and thus contributes to the harmonisation and further development 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 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 were not limited in time and did not require any extension or renewal. The authorisation to operate the existing nuclear installations expired 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). Due to the Russian war of aggression against Ukraine and the resulting energy crisis, the 19th AtGÄndG permitted power operation of the last three nuclear installations still connected to the grid – KKE, KKI 2 and GKN II – until the end of 15 April 2023. For this limited period of continued operation, only the FAs still present in the respective plant could be used to generate electricity. The last three nuclear installations ceased power operation on 15 April 2023. For nuclear installations, nuclear licensing procedures are therefore only carried out for major modifications (§ 7(1) AtG) and decommissioning (§ 7(3) AtG).

Thus, the following presentation of the nuclear licensing procedures 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.

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 (→ Article 14 (i), page 100).

A modification is essential in the legal sense if it can have more than obviously insignificant impacts on the safety level of the installation. This also applies if the modification leads to an increase in the safety level.

The Nuclear Licensing Procedure Ordinance lists certain types of modifications that require public notification. These cases are definitely considered to be essential modifications. In addition, modifications that may have an impact on the sequence of design-basis events and beyond-design events are also considered to be essential.

Essential modifications to a plant within the meaning of the Atomic Energy Act are limited to very few modifications during the plant's service life. One example of such a modification is the increase in thermal reactor output.

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.

Research reactors are generally subject to the same requirements for the licensing procedure as nuclear installations. As a rule, the regulations developed for nuclear installations are applied in stages depending on the risk potential of the respective research reactor facility, as described in the guideline on the application of the nuclear regulations for nuclear power plants to research reactors using a graded approach of 10 October 2023.

Nuclear licensing procedure

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 competent licensing and supervisory authority and their authorised experts. These documents are listed in detail in § 2 and § 3 AtVfV and their form is 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 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 competent 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 allowing 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 allowing 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 competent 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 competent 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 countries (§ 7a AtVfV) (→ Article 17 (iv), page 155), 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 competent 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 makes its assessment 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 competent licensing and supervisory authority of the *Land* informs BMUKN whether it considers the licensing procedure to be significant, or whether BMUKN issued requirements within the framework of federal oversight. Information is also given if BMUKN deems it necessary to involve the Federation in the individual case.

In performing these safety-related tasks within federal oversight, BMUKN is supported on technical issues by its advisory commissions RSK, ESK and SSK and in many cases by the expert organisation GRS. Where required, BMUKN states its position on the draft decision to the competent 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 the 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 applicants have to enclose an EIA report with their applications (§ 3(2) AtVfV). The first decommissioning licence is always a project subject to an EIA. For further licensing procedures, an EIA preliminary assessment may be carried out to determine whether an EIA is necessary or whether the preliminary assessment can already rule out the possibility that the project will have relevant environmental effects. The EIA 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 are the radiological consequences for the environment 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) sentence 1 AtG) such as the safety analysis report (§ 6(1)2 in conjunction with § 3(1)1 AtVfV).

Subsequently, the competent 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 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 forego 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. Further details are regulated by the AtVfV, which contains regulations on

- the conditions under which the competent licensing and supervisory authority may waive 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 competent licensing and supervisory authority, licence applicant and those who have raised the objections (§§ 8 to 13 AtVfV).

The competent 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 to inform 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 competent 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 BMUKN 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 competent licensing and supervisory authority can be appealed before administrative courts.

The AtG includes the necessary authorisation providing the basis for the competent licensing and supervisory authorities of the *Länder* to take action against an unlicensed construction or unlicensed operation of a nuclear installation. In particular, the competent 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 competent licensing and supervisory authority or if the required licence had been revoked. The competent 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, including the start of construction, operation and decommissioning. This supervision is performed by the competent 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 competent 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 competent licensing and supervisory authority were performed, on average, once per week and installation. Any staff representing the supervisory and licensing authorities have unrestricted access to the installations.

The competent licensing and supervisory authorities pay 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 competent licensing and supervisory authorities monitor, 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 (ISIs) 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 protection against malicious acts,
- 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 took place every working day or permanently.

The authorised experts consulted by the competent licensing and supervisory authorities 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). However, the competent licensing and supervisory authorities are not bound by the result of the examinations.

Consulted experts are commissioned and paid by the competent supervisory authority. Pursuant to § 21(2) AtG, the supervisory authority may have the fees of the experts reimbursed by the licence holder *"to the extent that they are limited to amounts that are reasonable in consideration of the required technical knowledge and special difficulties of the assessment, testing and investigation as remuneration for the expert's work"*. This prevents the licence holder from influencing the expert assessment.

The licence holders of the nuclear installations have to submit written operating reports to the competent 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. The time intervals at which the reports have to be submitted differ depending on the subject matter. Examples are:

- Monthly reports on the following issues:
  - Operation
  - Reportable events
  - On-going modification procedures
  - Radiation protection
  - Radioactive discharges
  - Waste management
  - Water chemistry
- Quarterly reports on the following issues:
  - Staffing
  - Immission monitoring
- Half-yearly reports on the following issues:
  - Report on measures taken due to events that occurred in other installations
- Annual reports on the following issues:
  - Safety Management System (SMS)
  - Root cause analysis
  - Reports to the RSK
  - Ageing management
  - Qualification and further training of staff
  - Waste management

Any radiologically and safety-relevant events must be reported to the competent 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) of the report in hand. 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), page 103).

7 (2iv) Enforcement of regulations and provisions

Enforcement by regulatory order, particularly in urgent cases

According to § 19 AtG, the competent 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 competent licensing and supervisory authority in case of an unlicensed mode of operation are dealt with in Article 7 (2ii) of this report.

In case of non-fulfilment of the licensing provisions or supervisory orders, the competent 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 competent licensing and supervisory 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 competent licensing and supervisory 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 themselves or for others 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.

While criminal sanctions can only affect natural persons, a fine can also be imposed on legal persons and associations of persons.

Experiences

Due to the intense regulatory supervision of the design, construction, commissioning, operation and decommissioning of nuclear installations (→ Article 7 (2iii), page 48), 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 competent 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 competent licensing and supervisory authorities of the Federation and the *Länder* (→ Figure 8-1).

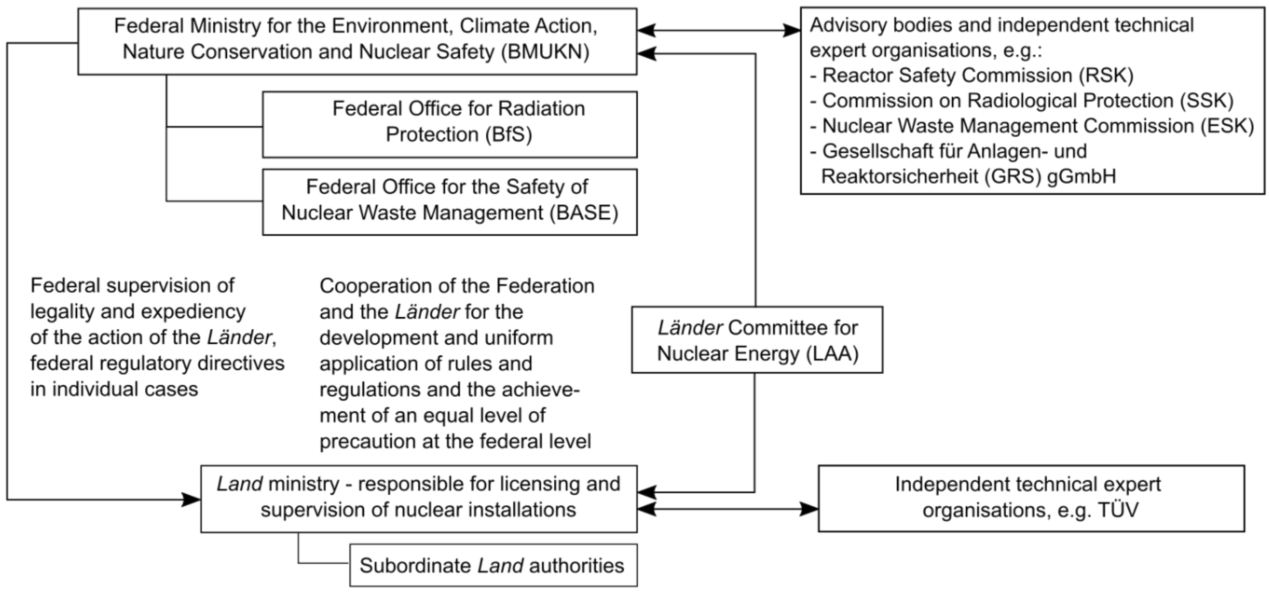

Figure 8-1 Structure of the regulatory body

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 competent licensing and supervisory authority of the Federation lies with BMUKN. The necessary human and financial resources are applied for by BMUKN from the annual federal budget.

Regarding the obligations under the Convention on Nuclear Safety, BMUKN 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 as well as 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 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 BfS in § 185 StrlSchG and BASE in § 23d AtG.

Assignment of competencies of the regulatory body

Responsibilities in the Federation and in the *Länder*

Competent federal authorities

BMUKN is the Federal Ministry competent for nuclear safety and radiation protection. In this function, BMUKN is responsible for the effective protection of people, the environment and assets from nuclear hazards and risks as well as, among other things, from harmful effects of ionising and non-ionising radiation. In addition, BMUKN is responsible for the organisation, staffing and financial resources of the competent licensing and supervisory authorities of the Federation.

Directorate-General S “Nuclear Safety, Radiation Protection” (→ Figure 8-3, page 59) of BMUKN comprises three directorates. Directorate S I performs tasks in the field of nuclear safety. Directorate S II is responsible for tasks in the field of radiation protection, including emergency preparedness and response. Directorate S III deals with the tasks relating to nuclear waste management.

In the fulfilment of the tasks relevant here, BASE and BfS belong to the portfolio of BMUKN.

Competent licensing and supervisory authorities of the *Länder*

In the AtG, the supreme *Land* authorities have been designated as competent licensing and supervisory authorities. The *Land* authorities responsible for enforcing the StrlSchG are defined in the respective ordinances of the *Länder*. The federal authorities responsible for enforcing the StrlSchG are defined in said Act.

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

Within the framework of decisions on licences, the competent licensing and supervisory authorities of the *Länder* examine the fulfilment of the licensing requirements. The concrete form implementation of the licensing procedure under the AtG are regulated in detail in the AtVfV.

The supervisory tasks of the competent licensing and supervisory authorities were listed in Article 7 (2iii) (→ page 48).

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 makes use of this option only in exceptional, individual cases as a last resort. Before this happens, BMUKN 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. In doing so, it takes over the competence in the subject matter.

Communication with the licence holder is the exclusive and inalienable responsibility of the *Länder* (competence to execute duties). This includes any legally binding external action.

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 the supervision manual.

The essential tasks of the Federal Government and the *Länder* are described in Table 8-1.

Table 8-1 Assignment of the regulatory functions to the competent licensing and supervisory authorities of the Federation and the *Länder*

<table>
<tr><th rowspan="2">Regulatory function</th><th colspan="2">Tasks and competencies of the regulatory body</th></tr>
<tr><th>Authorities of the Federation</th><th>Authorities of the Länder</th></tr>
<tr><td colspan="3">Main functions</td></tr>
<tr><td>Establishment of national safety requirements and regulations
[Art. 7 (2i), page 35]</td><td>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</td><td>Participation on the basis of consolidated findings and needs in connection with execution; supplementary administrative procedures of the respective Länder</td></tr>
<tr><td>Licensing system for nuclear installations
[Art. 7 (2ii), page 44]</td><td rowspan="3">Supervision of legality and expediency [17]
Checking of consolidated findings with regard to their relevance for standard national requirements</td><td>Checking of applications and notifications according to § 7 AtG, granting of licences and approvals</td></tr>
<tr><td>System of regulatory inspection and assessment of nuclear installations
[Art. 7 (2iii), page 48]</td><td>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</td></tr>
<tr><td>Enforcement of applicable regulations and of the terms of licences
[Art. 7 (2iv), page 49]</td><td>Implementation of necessary measures to avert hazards and for necessary safety improvements as well as improvement of protective and preventive measures</td></tr>
<tr><td colspan="3">Secondary functions</td></tr>
<tr><td>Regulatory safety research</td><td>Investigation of safety issues for standard requirements</td><td>Plant-specific studies</td></tr>
<tr><td>Monitoring of events, operating experience and implementation</td><td>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</td><td>Examination and assessment of events with regard to relevance for the safety of the nuclear installations as well as for protective and preventive measures</td></tr>
<tr><td>Radiation protection, environmental monitoring</td><td>Monitoring of exposure of the population and the federal territory</td><td>Plant-specific monitoring of emissions and immissions (exposure of workers and in the environment)</td></tr>
</table>

[17] 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.

Regulatory function	Tasks and competencies of the regulatory body	
	Authorities of the Federation	Authorities of the *Länder*
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, if required, 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

blue	Leading function, execution within the area of competence
light blue	Function with separate competences but common objectives
white	“Federalism function”, supervision with regard to legality and expediency or participation

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, BASE was established 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 BMUKN and the competent 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 (→ Article 14, page 100, Article 18, page 157, and Article 19, page 166),
- system for the application of operating experience (→ Article 19, page 166),
- radiation protection (→ Article 15, page 113),
- emergency preparedness (→ Article 16, page 128), and
- international cooperation (Preamble vii and viii, Article 1).

Table 8-2 shows the competent licensing and supervisory authorities of the *Länder* in which nuclear installations in terms of the Convention (→ Introduction, page 15) are located.

Table 8-2 Competent licensing and supervisory authorities of the *Länder* with nuclear installations in terms of the Convention

<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 II</td><td>Ministry of the Environment, Climate Protection and the Energy Sector of Baden-Württemberg in agreement with the Ministry of the Interior, Digitalisation and Local Government 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 2
Gundremmingen C</td><td colspan="2">Bavarian State Ministry of the Environment and Consumer Protection</td></tr>
<tr><td>Lower Saxony</td><td>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>Brokdorf</td><td colspan="2">Ministry of Energy Transition, Climate Protection, the Environment and Nature Schleswig Holstein</td></tr>
</table>

As a matter of principle, the competent 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

BMUKN and the competent licensing and supervisory authorities of the *Länder* have prepared a common 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. This supervision manual adopted by the LAA describes the core processes of the supervision of nuclear installations (power operation and post-operation) and the inter-faces between the nuclear supervision of the Federation and the *Länder*. It serves as a common basis for action and cooperation for the competent licensing and supervisory authorities of the Federation and the *Länder*. The supervision manual was expanded in the summer of 2023 and the processes were reviewed with regard to their relevance for nuclear installations under decommissioning and for research reactors in operation and under decommissioning. It serves as a common basis for action and cooperation for the competent federal and *Länder* licensing and supervisory authorities and was last updated in June 2024.

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 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 staff of the competent licensing and supervisory authorities of the *Länder* and BMUKN. It supports the Federation and the *Länder* in the execution of the AtG and the 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 competent 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 licensing and supervisory authorities of the *Länder* and the Federation develop, in consensus, respective regulations. These are announced by BMUKN in the Federal Gazette. BMUKN 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.

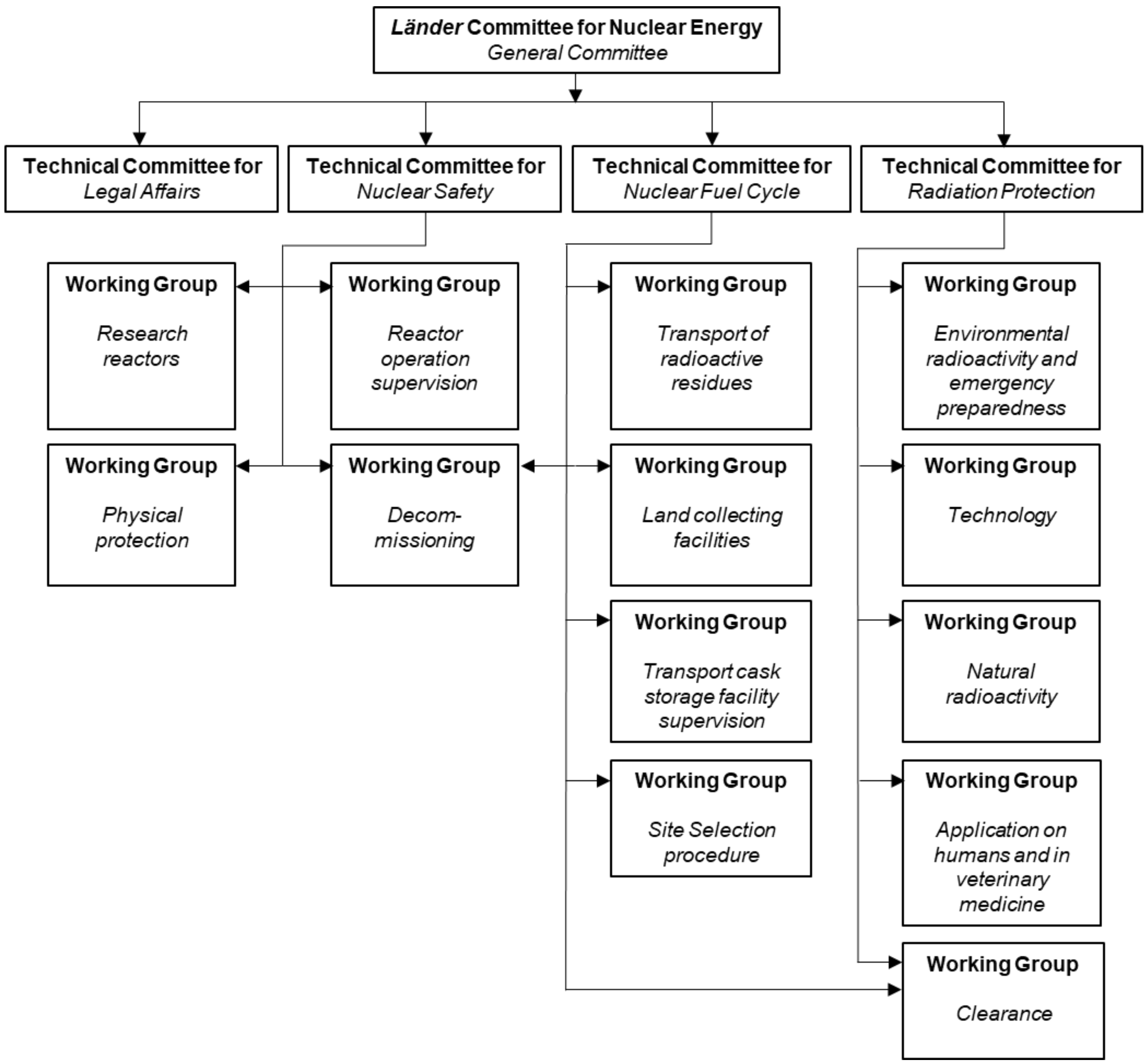

Figure 8-2 Structure of the *Länder* Committee for Nuclear Energy (LAA)

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 BMUKN. Directorate-General S "Nuclear Safety, Radiological Protection" of BMUKN 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.

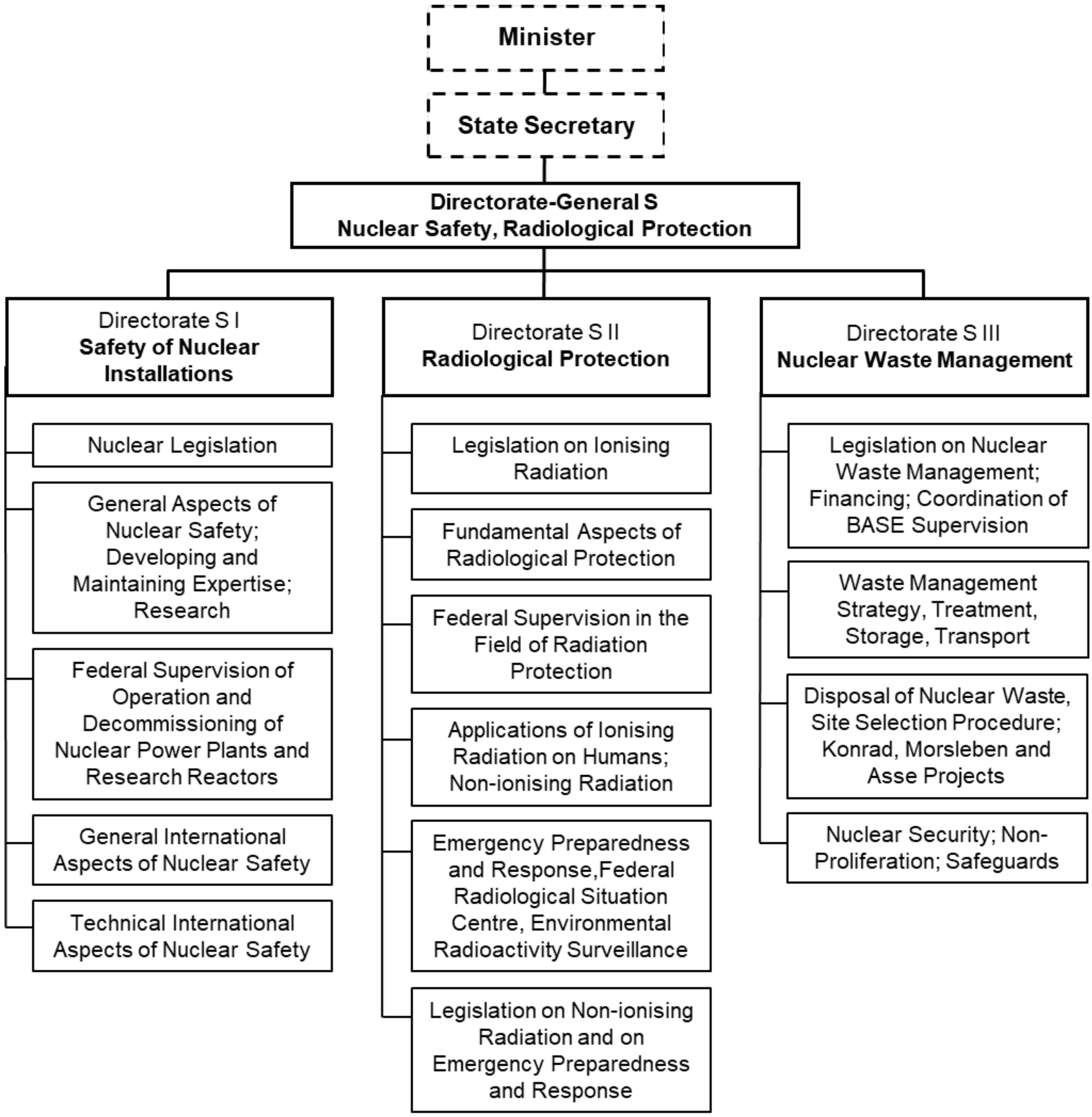

Figure 8-3 Organisation of Directorate-General S at BMUKN

Staffing of BMUKN

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

The legal civil servants or public service employees 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), studies at a university of applied sciences or university studies completed with a bachelor's degree (higher service). Apart from that, there are no specific regulations on training and qualification.

At BMUKN, the responsibility for fulfilling the obligations under the Convention on Nuclear Safety primarily lies with Directorate S I and involves around 40 staff. Of these, about 25 have come from a scientific-technical background and 15 have a legal or non-technical (especially administrative staff) background.

In Directorate S II "Radiological Protection", about 19 employees are entrusted with tasks that are related to the Convention, e.g. with radiation protection in nuclear installations or emergency preparedness and response.

Directorate S is supported by a directorate for central function (e.g. personnel and budgetary matters, infrastructure tasks and general services).

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

BASE as a regulatory, licensing and supervisory authority in the field of waste management has been continuously built up since 2016. The tasks in terms of the Convention are performed in the department "Nuclear Safety" in cooperation with the department "Research and International" by around 35 staff members.

Competent licensing and supervisory authorities of the *Länder*

The competent licensing and supervisory authorities of the *Länder* for the supervision of nuclear installations are the ministries (supreme *Land* authorities) determined by the *Land* governments. Table 8-2 shows the ministries competent for nuclear installations in terms of the Convention. Within the ministries, the tasks of the competent 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.

In the same way as at federal level, it also applies for the *Länder* that the directorate for the supervision of nuclear installations is usually supported by a further organisational unit of the ministry which is, in many cases, a directorate for central functions (e.g. human resources and budgetary affairs, infrastructure tasks and general services). For illustration purposes, Figure 8-4 shows the basic organisation of a *Land* ministry directorate for the supervision of nuclear installations.

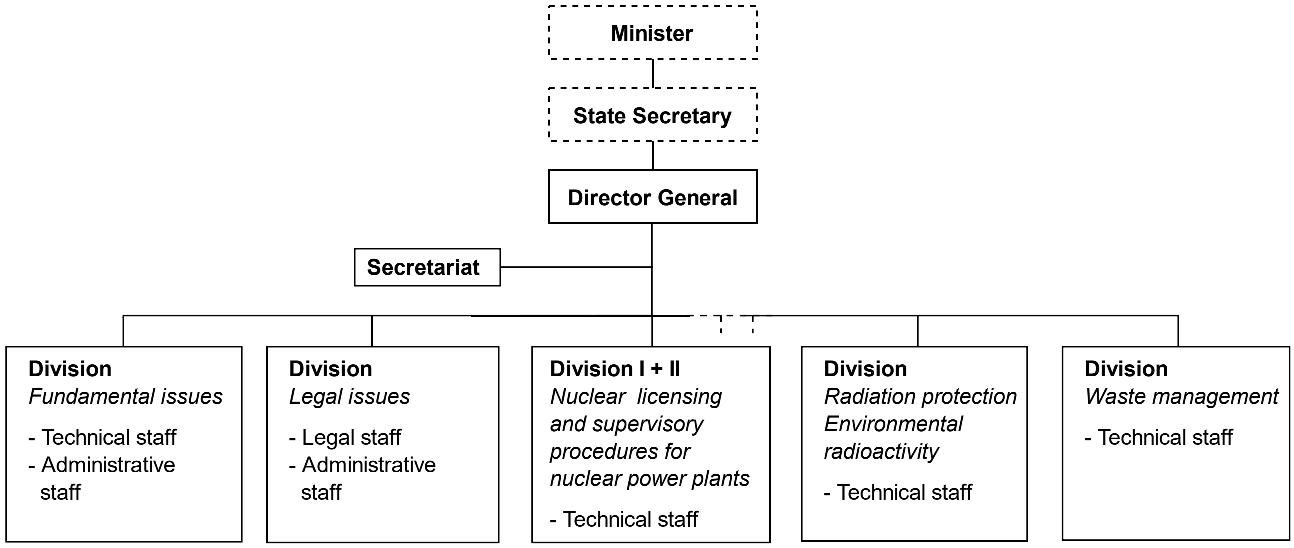

Figure 8-4 Basic organisation of a *Land* ministry directorate for the supervision of nuclear installations

Staffing of the *Länder*

The directorates for the supervision of nuclear installations mainly employ scientific and technical specialist staff, especially engineers and scientists, to some extent also industrial psychologists. They also have legal experts and administrative staff. All these directorates carry out reviews and assessments as well as tasks related to the execution of the 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 competent 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 competent 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 competent 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 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 professional competence of their staff, the required number of staff as well as an expedient and effective organisation. So far, the fluctuation of well-trained specialist staff at the level of the federal and *Land* authorities as well as at the level of the operators of nuclear installations has been low. Through strategic human resource management and human resource development, staff members are identified within the organisations for specific tasks and motivated to apply. The promotion of women has a high priority.

A large number of experienced staff of the competent 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 competent licensing and supervisory authorities, which is also addressed in the concept of the Federal Government. Vacancies are attractive for young people with a university degree in a relevant area of licensing and supervision, among other things because of the lifelong employment as a civil servant. Especially in the areas of waste management and radiation protection, there will continue to be attractive tasks in the future. Available positions can often only be filled with applicants without relevant nuclear knowledge. This circumstance is countered by internal and external training and further qualification measures, internal job rotations as well as suitable measures to maintain competence and transfer knowledge. Three years are assumed until new staff members are fully trained.

On 26 August 2020, the Federal Cabinet adopted the "Strategy for Competence Building and the Development of Future Talent for Nuclear Safety"[18]. The aim of the Federal Government's framework concept is to maintain competence and future talent development oriented towards safety and to continue to actively promote the German concept of safety at an international level. As part of the development process for the strategy, needs/demand analyses were first carried out in order to plan specific measures in advance. The needs/demand analyses were carried out in different stages, with the first step being to identify needs at federal level (BMUKN, BASE, BfS, BGE, BGZ). In a second step, needs beyond the federal level (e.g. *Länder*, consultancies, specialist organisations, associations) were identified. The surveys were carried out with the help of questionnaires.

Valid indications of future challenges can be gained from the evaluation of the needs/demand analyses. Various fields of action are identified on which measures to maintain and build expertise and specialist capacities should focus.

The first area of action is education and teaching. Professional qualifications are the key to long-term knowledge maintenance and the recruitment of specialised personnel. A professional qualification guarantees the acquisition and further development of skills that can be used in a wide range of tasks for the continual improvement of nuclear safety. This also includes making career opportunities visible through various approaches such as a career orientation day, which offers insights into the work of licensing and supervisory authorities dealing with nuclear safety and waste management issues.

Another area of action is research and development. Continuous state-funded safety-oriented research and development is necessary in the long term in order to maintain and further develop technical and scientific competence in the dynamically developing areas of nuclear safety. The promotion of safety-oriented research and development at universities and non-university research and scientific institutions plays a decisive role in attracting young talent. Attractive teaching and research conditions can motivate students (and young scientists) to specialise in the field of nuclear engineering and to gain further qualifications in these areas. State-funded research contributes to the training of young scientists and the further development of the state of the art in science and technology. As part of BMUKN's project funding programme for safety research for nuclear facilities, it is possible to specifically promote the next generation of specialists in nuclear safety. Examples of this include the funding of doctoral positions as part of the established funding initiative to maintain expertise in nuclear engineering and the funding of junior research groups at universities. BMUKN's project funding is accompanied by funding for basic research from the Federal Ministry of Research, Technology and Space (BMFTR). BMFTR funding includes both project funding and institutional funding for research activities at the Helmholtz Association of German Research Centres (HGF). The Nuclear Waste Management, Safety and Radiation Research (NUSAFE) programme provides the HGF with

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[18] „Konzept zur Kompetenz- und Nachwuchsentwicklung für die nukleare Sicherheit", BMWi, August 2020; https://www.bmuv.de/themen/nukleare-sicherheit/konzept-zur-kompetenz-und-nachwuchsentwicklung-fuer-die-nukleare-sicherheit

a framework for basic research into nuclear safety. With “FORKA – Forschung für den Rückbau kerntechnischer Anlagen” (Research for the Decommissioning of Nuclear Facilities), BMFTR has created a framework for research projects on the decommissioning and dismantling of nuclear facilities and the disposal of the resulting radioactive waste. NukSiFutur is a BMBF (now BMFTR) funding guideline for the promotion of young scientists in the field of nuclear safety by setting up summer schools for networking, integrating industrial activities and strengthening nuclear safety research (e.g. junior research group with possible appointment to a tenure-track professorship).

Another area of action is the maintenance/transfer of knowledge within the competent licensing and supervisory authorities. In some cases, available positions can only be filled by applicants without relevant nuclear expertise. This situation is countered by internal and external training and further training measures, internal job rotations and suitable measures to maintain competence and transfer knowledge. A knowledge transfer procedure is in place for employees who leave to ensure that knowledge is retained. In addition, the transfer of knowledge is ensured by the supervisory manual, which incorporates the procedures and experience of the regulatory authority in its creation and evaluation. This compendium

- presents the basic principles and framework conditions of nuclear supervision,
- describes the concept of supervision and the procedures for its execution, and
- documents the know-how and know-why gained during execution.

It thus serves to maintain and transfer knowledge and experience.

Another area of action is the advanced and continuing training of existing and new staff.

In order to establish sustainable structures that ensure high-quality and long-term advanced and continuous training opportunities, BMUKN has decided to set up two qualification networks: one in the field of nuclear safety (safety of nuclear installations and nuclear waste disposal), hosted by BASE, and one qualification network for radiation protection, hosted by BfS. The networks were established in 2023 and serve as coordination platforms. Their objectives are to connect, coordinate and specifically support stakeholders, expertise and training and qualification opportunities through central bodies. Accordingly, their tasks include coordinating and connecting existing training programmes with the aim of pooling demand from providers, supporting internships, dual studies and other training programmes and creating supplementary programmes to close existing and future gaps. Existing providers (e.g. research centres, universities) are to be strengthened through networking.

In addition to the above-mentioned research, development and demonstration activities, three competence associations have been founded: the Alliance for Competence in Nuclear Technology (KVKT), the German Association for Repository Research (DAEF) and the Competence Network Radiation Research (KVSF). KVKT, KVSF and DAEF provide forums for the exchange of information and experience between their associated members, which include a large number of research institutions at national level in the field of nuclear reactor safety, waste management and repository research, including research institutes, universities, expert organisations and project delivery organisations.

Maintaining competence and personnel development at the nuclear regulatory authorities

So far, it has largely been possible to compensate any loss of experience during the generational change within the nuclear regulatory authorities of the Federation by the documentation of knowledge, by interviewing those who were about to retire and by the commitment of the junior staff. Activities for a controlled knowledge transfer of staff leaving the authorities are currently being intensified. In particular, successor appointments are planned in such a way that a timely handover and transfer of knowledge can take place in a targeted and systematic manner.

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 trainings during an introductory phase as well as by on-the-job training at the authorities.

The technical specialist training and further qualification of the staff takes place, among other things, through participation in seminars for staff of the authorities organised by GRS on behalf of BMUKN for the training and further qualification in particular for younger staff at regular intervals and on various safety-relevant topics as well as through participation in external national and international specialist events. Until the middle of 2024, staff of the federal nuclear regulatory authority had taken part e.g. in simulator and glass model training courses at Gesellschaft für Simulatorschulung (GfS). Issues of specialist training and further qualification are addressed, among other things, in the co-operation talks regularly held between all staff members, also long-standing and experienced staff, and executives.

Maintaining competence also plays an important role for the competent licensing and supervisory authorities of the *Länder*. Newly recruited staff members take part in the knowledge transfer of the competent 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 the 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. This catalogue helps to ensure the division's required competence and qualification.

In addition, also the long-standing and experienced staff of the competent licensing and supervisory authorities keep their technical qualification continuously up to date and participate in the relevant training activities. If they leave the authority, for example due to retirement, knowledge is transferred to colleagues i.a. through discussions, interviews, team inspections, collaboration on processes and joint participation in meetings.

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 competent 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 (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. In addition, the portal includes areas where documents and results of research and development projects financed by BMUKN 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.

With the introduction of the PNS, a tool was created that enables the efficient digital exchange and distribution of information between the various nuclear regulatory authorities and their expert organisations in the field of nuclear safety. More than 130,000 documents and about 300 knowledge pages are available, so that the PNS serves as a computer-based knowledge management system. It supports the communication between the German nuclear supervisory and licensing authorities in an efficient way and enables all authorised members to quickly access and exchange information on national and international developments and the state of the art in the field of nuclear safety, which are to be taken into account for the continuous improvement of nuclear safety in Germany.

Financial resources

§ 23 AtG stipulates that the nuclear licensing and supervisory authorities shall have adequate financial and human resources to fulfil their statutory tasks. § 193a StrlSchG provides for an identical regulation for the competent radiation protection authorities. The financial resources available to the competent 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 (BMUKN), 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 AtG and the StrlSchG (AtSKostV). The costs are paid by the licence holder to the treasury of the respective *Land*. A modification requiring a licence costs between 500 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 and 500,000 euros. The remuneration for the authorised experts consulted is also reimbursed by the applicant or licence holder as expenses.

BMUKN receives an annual budget of approximately 65 million euros from the federal budget covering project funding for safety research for nuclear facilities as well as for research, investigations and the like in the fields of nuclear safety and radiation protection and for international research projects in this area. The field of nuclear safety includes e.g. the evaluation and assessment of operating experience, studies on special safety-related issues and further development of technical requirements for nuclear installations as well as work on technical and other specific questions in connection with the licensing and supervision of nuclear installations. Among other things, the budget is used for financing the work of the advisory commissions and for involving external expert bodies in international cooperation.

Management systems

Management system at the nuclear regulatory authorities 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. In addition, new principles for good cooperation and leadership were introduced in October 2020 at BMUKN, which are guiding principles for all employees, regardless of function level or career group. These specify the expectations and requirements for all management staff, with their special responsibility for fulfilling the demanding tasks of BMUKN, and set quality standards against which good cooperation and leadership are regularly measured in staff surveys and leadership feedback.

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.

At BASE, an integrated management system (IMS) ensures that internal routines and the work results are continuously re-examined and that appropriate improvements are made when needs are identified. The IMS is based on recognised international management system standards; environmental management is evaluated in accordance with the European EMAS regulation, quality management is currently based on ISO 9001 and certification in accordance with ISO 9001 is being prepared. Compliance with the system requirements is monitored in regular internal audits, and the IMS is evaluated annually with regard to its appropriateness and suitability.

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

The work routines and processes of the competent 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.

The basic principles for the performance of the supervisory procedure are laid down in the AtG and in the statutory ordinances that concretise these principles, as well as in the substatutory regulations that must also be observed. These regulations and their implementation in administrative practice have been incorporated into a supervision manual in the form of instructions for specific processes. The work routines and procedures laid down in the supervision manual are largely of a general nature and also remain valid in the post-operational phase or during decommissioning. These include, for example, the performance of plant inspections, the modification procedure or the supervision of clearance procedures. Where necessary, the supervision manual is extended or emphasised to include processes specific to decommissioning or general processes, such as the monitoring of dismantling work, the absence of impacts of dismantling on residual operation, handling of radioactive waste, clearance or α-contamination. Other areas, e.g. fuel handling or severe accidents, lose their relevance as dismantling progresses. In addition, the monitoring of residual operation is adapted to the decreasing nuclear risk and the decreasing number of remaining safety-relevant SSCs.

In addition to these and the internal management systems described in the AtVfV, there are other ways to ensure coherent administrative practice by the competent licensing and supervisory authorities. In addition to the provisions of the GG on the framework of federal executive administration according to Articles 87c, 85(3) and (4) GG, which preserve the basic rules for federal supervision of the legality and expediency of measures taken by the *Land* authorities, the competent licensing and supervisory authorities have described their common understanding in the jointly prepared supervision manual. In addition, the forum of the LAA and its technical committees and working groups plays a decisive role in ensuring a coherent, federally uniform enforcement of nuclear and radiation protection law by the various *Land* authorities.

Support by the federal offices, advisory commissions and authorised experts

Federal Office for Radiation Protection (BfS)

BfS is a subordinate authority of BMUKN in the field of radiation protection and nuclear safety and supports BMUKN 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 (National Dose Register),
- the control programme for emission monitoring of nuclear installations,
- large-scale monitoring of environmental radioactivity, and
- in the event of an emergency 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 BMUKN and BfS within the framework of the annual planning.

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

BASE is the central federal authority for the safe handling and management of radioactive waste from the nuclear energy sector and performs the following statutory tasks:

- the granting of licences for the storage and transport of nuclear fuel, in particular in the form of irradiated nuclear fuel and large sources,
- monitoring and public participation in the search for and selection of a site for a repository for high-level radioactive waste (site selection procedure; carried out by BGE),
- performance of the strategic environmental assessments and environmental impact assessment in accordance with the Environmental Impact Assessment Act (UVPG) for the plan in the site selection procedure and after screening for surface and underground exploration programmes,
- long-term documentation for data and documents from interim storage and disposal,
- task-related research in the field of safety of nuclear waste management, participation and communication, and
- supervision under nuclear law and licensing of repositories, including approvals under mining law and permits under water law.

  Transitional provisions apply to the Konrad and ERAM repository projects. At present, the licensing tasks under mining and nuclear law, mining supervision and water law permits for these two projects are still the responsibility of the *Länder*. With the approval of the commissioning of the Konrad repository, which is currently under construction, and after completion of the ERAM decommissioning procedure, both the nuclear licensing responsibility and the mining supervision will be transferred to BASE. For the Asse II mine, these responsibilities remain with the *Land* of Lower Saxony. However, nuclear supervision of the Asse II mine is also the responsibility of BASE (§ 58 AtG, transitional provisions).

The “Nuclear Safety” department, in cooperation with the “Research and International” department, supports BMUKN in the following priority areas related to the Convention on Nuclear Safety:

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

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

BMUKN 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. The ESK provides advice to BMUKN and BASE 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. They are appointed by BMUKN but are independent and not bound by instructions. They work on an honorary basis and come primarily from universities, research institutions, technical safety organisations and the industry. 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 RSK's consultations and on how the authorities deal with the results of the consultations, see process 11 in the supervision manual of the Federation and the *Länder* and on the websites of the above-mentioned bodies[19].

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 competent licensing and supervisory authority is not bound by the results of the examinations of the authorised experts.

BMUKN draws on the external expertise of several technical expert organisations. In particular, these are GRS, Brenk Systemplanung GmbH, Physikerbüro Bremen and Öko-Institut e.V.

The competent licensing and supervisory authorities of the *Länder* usually seek advice from the major technical expert organisations of the TÜVs (TÜV Nord, TÜV SÜD and TÜV Rheinland) as the general expert. As a rule, framework agreements exist between the competent licensing and supervisory authorities of the *Länder* and the TÜVs, which oblige TÜVs to perform certain tasks in the long

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[19] RSK: https://www.rskonline.de; SSK: www.ssk.de/DE/Home/home_node.html; ESK: www.entsorgungskommission.de/

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 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. Framework agreements are in place with GRS to deal with supervisory issues relating to nuclear security. In addition, the licensing and supervisory authorities commission other expert organisations, such as the Physikerbüro Bremen, Öko-Institut e.V. or ESN Sicherheit und Zertifizierung GmbH, for special issues.

With the involvement of authorised experts, 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 competent licensing and supervisory authority by name or are known to it.

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

Integrated Regulatory Review Service (IRRS) Mission 2019 and Follow-Up 2023

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 § 24b(1) AtG. The European Nuclear Safety Regulator Group (ENSREG) and the IAEA have agreed in a Memorandum of Understanding to use the Integrated Regulatory Review Service of the IAEA for this purpose.

At the invitation of BMUV (now BMUKN), the follow-up mission to the second IRRS mission to Germany took place from 9 to 16 October 2023. The implementation of the recommendations and suggestions made during the main mission in 2019 by the federal and *Länder* nuclear licensing and supervisory authorities was reviewed. The scope of the follow-up mission remained unchanged and covered all nuclear installations, facilities and activities operated and pursued in the Federal Republic of Germany with the exception of shipment, radiation sources, security interfaces and aspects of public and medical radiation exposure.

The final report confirms Germany's commitment to improving and further developing the national supervisory system for the safety of nuclear installations and facilities. The progress made since 2019 includes i.a. the enhanced harmonisation of supervision between the regulatory authorities, the promotion of safety culture in supervisory authorities through regular assessments, the introduction of a national strategy for competence-building, the increased involvement of the staff of all supervisory authorities in the international exchange of experience, the strengthening of emergency preparedness and response through the adoption of the Federal Government's General Emergency Plan, including the establishment of the Radiological Situation Centre, and the improvement of conformity of the regulatory framework with the IAEA's safety standards.

As a result, all six recommendations and almost all of the 25 suggestions from the main mission were considered to have been implemented. The implementation process could not be completed for two suggestions due to ongoing or pending activities. Two new suggestions were also made. The areas affected are the further development of the integrated management system at BASE and the *Länder* and the decommissioning and disposal of radioactive waste with negligible heat generation.

The successful completion of the IRRS Follow-up Mission 2023 marked the end of the second cycle of the peer review process, which is mandatory within the EU.

The Advance Reference Material (ARM)[20] as well as the final report on the IRRS Mission 2023 were published on BMUKN's website[21].

8 (2) 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 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom of 25 July 2014 establishing a Community framework for the nuclear safety of nuclear installations.

Realisation in Germany

The competent licensing and supervisory authorities of the Federation and the *Länder* are administrative state authorities. The 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 licensing and supervisory authorities on *Länder* level and the powers of supervision and instruction held by the Federation.

The principle of separation of Article 8 (2) of the Convention on Nuclear Safety is adhered to on the basis of the organisational arrangements implemented. The effective separation of the bodies responsible for nuclear licensing and supervision from those responsible for general energy policy is ensured by the fact that different ministries 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), page 45, Article 7 (2iii), page 48 and Article 8 (1), page 61).

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 BMUKN. BMUKN does not fulfil any functions relating to the use and promotion of nuclear energy.

BMUKN pursues the development of new safety solutions to derive important knowledge concerning the safety of German nuclear installations in operation or also for the further development of nuclear safety worldwide.

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.

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20 „Advanced Reference Material", IRRS Follow-up Mission 2023, Germany, https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/arm_ger_irrs_fu_mission_2023_bf.pdf

21 „Report of the IRRS Follow-up Mission to Germany", Oktober 2023, https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/irrs_follow-up_mission_final_report_bf.pdf

These shareholders are also commercial enterprises under civil law, usually joint-stock companies (→ Article 11 (1), page 84) and have no influence on the safety-directed action of the competent licensing and supervisory authorities.

Reporting of the regulatory body

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

BMUKN informs the Committee on the Environment, Climate Action, 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, BMUKN informs about the publication of detailed monthly and annual reports on reportable events in German nuclear installations and research reactors through BASE on its 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 communication formats, through which the public, in particular in the vicinity of the installations, is informed verbally about safety issues and operating processes of the nuclear installations in regular events and questions are answered.

On 16 February 2018, the Portal on Safety in Nuclear Engineering[22] was launched in German and English. The portal was developed by the BMUKN together with the *Länder*, the BfS and BASE. The aim is to provide the population with simplified access to information on the activities of the competent 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 licensing and supervisory authorities are provided as well as basic knowledge on nuclear technology.

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22 Information portal of the Federal government and the *Länder*: www.nuklearesicherheit.de

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 2014/87/Euratom of 8 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 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 the construction and for operation could only be granted if the applicant proved 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 was only to be granted if were no doubts as to the trustworthiness of the applicant and the persons responsible. In addition, these persons had to 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 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), page 173 and Article 19 (vii), page 177).

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, page 78).

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 competent 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

- about the specified normal operation of the nuclear installation, and
- about 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 (→ Article 10, page 78 and Article 13, page 96) 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 IMS, 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 SiAnf 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 and 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 licensing and supervisory authority that the requirements resulting from the "Guideline Concerning the Proof of the Technical Qualification of Nuclear Power Plant Personnel" are fulfilled, adapted to the current plant state.

The licence holders of the German nuclear installations are members of vgbe, the international technical association for generation and storage of power and heat. vgbe 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 vgbe, joint research and development in the area of "nuclear power plants" is conducted and promoted. vgbe 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 carried out in nuclear procedures for plants in power operation 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, page 29 14 (i), page 100 and Article 16 (1), page 129).

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), page 167) 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 competent licensing authority or to the approval of the nuclear supervisory authority

The licence holder’s PBO is a safety specification document and contains the detailed structure of the organisation. The structure basically consists of the (safety-relevant technical) departments at a higher level with their sub-departments. The PBO further specifies the tasks and responsibilities of the individual departments and sub-departments. The authorised expert consulted checks whether the new organisation complies with the legal framework and the principles of organisational doctrine, e.g. the clear assignment and congruence of responsibilities, tasks and powers, the designation of the necessary deputies, the definition of the interfaces between the (sub)divisions and the appropriate number of directly subordinate persons, each of whom is led by the (sub)division head. The authorised expert also assesses the required change in processes due to the change in organisational structure. Furthermore, the planned change management during preparation, implementation and after implementation (e.g. communication, training, team building, evaluation of effectiveness) is assessed. Based on this assessment, the authority evaluates and decides on the licence holder's application. The result of this decision can be a licence or regulatory approval in the supervisory procedure, depending on the extent of the change. In case of a substantial change in the structural organisation, a licence is required. In the case of minor changes, approval by the supervisory authority is required. This applies, for example, to the reallocation of tasks within a division, e.g. between its sub-departments. In addition to a change in the organisational structure, a change in the workflow organisation (processes) is also an organisational change. The safety-relevant processes are laid down in a number of different safety specifications and a variety of more detailed operating procedures. Such changes also require review and assessment by the authority.

Within the framework of supervision, the authorities of the *Länder* use various occasions for meetings with those responsible at the plant and the managing directors. These discussions focus, for example, on staffing and personnel planning, technical improvements, safety management and safety culture as well as maintaining and promoting motivation and know-how in connection with the German decision to phase out nuclear power. The aim of these discussions is an exchange between the authority and the licence holder on the general safety assessment of the plant and the company's longer-term strategy, goals and projects. In such discussions, the authority also gains an impression of how the managing directors communicate safety issues and how they act. In discussions with middle management and other staff, the authority checks how the messages and actions of top managers are perceived by their employees. In addition to these more general discussions, the supervisory authority also carries out specific inspections of the integrated management systems and specific measures taken by the licence holder to promote the safety culture.

In addition to the required technical qualification (→ Article 11 (2), page 86), the competent supervisory and licensing authorities also check the trustworthiness of the responsible persons of the licence holder and all persons working in safety-relevant areas. 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 competent licensing and supervisory authority also checks the trustworthiness of the applicant or licence holder (of a corporation) or the persons representing them (e.g. the board members or general management).

The verification of trustworthiness is initiated by an application submitted by the licence holder (not the person to be checked) on the basis of the Nuclear Trustworthiness Verification Ordinance (AtZüV). The verification is based in particular on information from the police and constitution protection authorities, on fully disclosed information from the Federal Central Criminal Register and, in individual cases, on information from the Federal Parliamentary Commissioner for the Victims of the SED Dictatorship. The verifying authority evaluates the information obtained to determine whether, in an overall assessment of the individual case, there are any doubts about the trustworthiness, in particular whether there is a risk of behaviour that could endanger the nuclear safety of the nuclear installation in question. If there are no doubts, the authority that performed the trustworthiness verification will inform the authorised applicant accordingly.

The trustworthiness verification is valid for five years. If facts become known during this period that could give rise to doubts about trustworthiness, a new check can be initiated before the period of validity expires. The trustworthiness verification is valid nationwide. The companies inform each other about trustworthiness verifications performed in other *Länder* by means of so-called cross-reports. The proper handling of these cross-reports by the operators is subject to regulatory supervision.

Altogether, all supervisory activities of the competent 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 ISI

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 management on site 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(2) AtG. There, the guiding principle of the AtG, which is the protection of life, health and real assets against the hazards of nuclear energy and the harmful effects of ionising radiation, is specified. 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 SiAnf 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 IMS, which contains all safety-related objectives and requirements to be considered. It also contains the task of the licence holder to maintain a highly developed safety culture and to continually improve it.

Priority to safety is further specified in the SiAnf 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 the safety standard KTA 1402. Both the SiAnf and safety standard 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 safety standard KTA 1402 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 guidelines to giving priority to the safety of the nuclear installations over all other business objectives (→ Article 9, page 72). 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. Due to the low radiological risk potential, the focus is shifting further towards conventional safety issues, in particular occupational safety, as dismantling progresses.

The safety of the installation is one of the primary goals of the licence holder. Strategic personnel management motivates employees to optimally contribute their experience to the operation of the installation. In addition, the processes are made transparent and the employees are given the opportunity to critically question the processes, report errors and thus contribute to the optimisation of the processes. The analysis of incidents and near-miss events leads to measures to improve occupational safety, to optimise existing instructions or to create new ones, to checklists and to the passing-on of knowledge in training courses. Furthermore, measures to prevent the reoccurrence of an event are derived and their effectiveness is evaluated.

As a “general criterion” in the sense of “general” for the effectiveness of the measures in the areas of human factors and organisation, it could be mentioned that fewer events occurred that are attributable to human and organisational aspects. However, in view of the overall low number of events in relation to the large number of activities, this is not a relevant measure. The RSK took up this issue with the publication of a recommendation on assessing the effectiveness of measures to prevent recurrence in 2019[23].

Appropriate remedial measures are derived from the causes identified in a root cause analysis. There are various methods such as interviews, questionnaires and observations (e.g. as part of the “Manager-in-the-Field” programme) that help to assess the effectiveness of the measures. Depending on the specific objective of the measures, these methods are to provide information on previously defined criteria. Such criteria can be the observed safe working practices, the appropriate use of error prevention tools, the acceptance of an organisational change by the employees, the correct answers of the participants in a training course or the results of a self-assessment of the safety culture.

The greatest strength of reviews is that experts from other power plants carry out the assessment and thus contribute their views and experience. This results in a broader learning approach for the respective power plant. This can counteract a certain “operational blindness”. Another advantage of reviews is that they are usually carried out by a whole team, which makes the assessment more objective.

The limitations of reviews may lie in the fact that, in general, they can only utilise a small period of time for the assessment. As a result, those concerned have little time to demonstrate their good implementation. In addition, the review team has less time to identify deficiencies.

Already in 2008, before publication of the safety standard KTA 1402 in 2012, the German licence holders of nuclear installations presented the VGB guideline to safety management “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”) (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.

[23] RSK recommendation on assessing the effectiveness of measures to prevent recurrence of events (“Bewertung der Wirksamkeit von Maßnahmen zur Vermeidung der Wiederholung von Ereignissen”), 512th meeting of the RSK, 22/23 October 2019, https://www.rskonline.de/sites/default/files/reports/epanlage1rsk512hp.pdf

The VGB guideline was introduced into the process of drawing up safety standard KTA 1402 by the licence holders. The safety culture assessment system of the vgbe (vgbe-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 competent licensing and supervisory authorities are informed about the performance and main results of the vgbe-SBS.

The licence holders have set up long-term personnel programmes in order to meet their safety responsibilities. New training programmes have been developed for the special requirements of decommissioning. After final shutdown and removal of the nuclear fuel, the requirements for know-how and expertise focus more on dismantling, waste management and radiation protection, while nuclear power engineering becomes less important. There are still students of engineering and radiation protection, as these subjects are also relevant in other industries and in medicine. Additional specialised knowledge for decommissioning and for the operation of the remaining safety-relevant systems such as ventilation or energy supply systems is trained on site. Maintaining a high safety culture and ensuring staff motivation are the responsibility of the licence holders. Instruments such as the vgbe-SBS and staff surveys are used to assess the motivation, expectations and concerns of personnel at the facilities. The results are used to develop appropriate measures. The following measures taken by the licence holders are subject to supervision.

- Specific measures for motivation:
  - Give staff a clear perspective for their professional future, either in decommissioning, in different business areas (large utilities) or in retirement
  - Communicate to staff the importance of nuclear safety to the last day and appreciate their high level of professionalism
- Specific measures related to know-how:
  - Maintaining proven training programmes and recruiting new staff years before experienced staff retire

Regulatory review

Within the framework of licensing of a nuclear installation and within the framework of supervision of its operation, the competent 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 competent 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 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 (iii), page 170).

The meetings and discussions with the licence holder's management staff are the methods by which the supervisory authority reviews the priority of safety at the strategic (management) level. In such meetings, not only safety issues are discussed. The supervisory authority also reviews the statements made by managers by inspecting documents (annual objectives of the company/nuclear installation, agendas of internal meetings, power point presentations used by managers for communication, etc.).

In addition to such meetings at the management level, the supervisory authority also obtains information and insights into the safety priorities of the licence holder by evaluating documents such as reports with event analyses or applications for planned modifications.

The supervisory authority checks the priority of safety within the framework of inspections. Examples of regular inspections are the following:

- Inspections of the safety management system and its processes: The supervisory authority checks records of safety performance indicators, results of internal audits, the implementation of action plans, the improvement of processes, etc. The supervisory authority or authorised experts consulted carries out on-site inspections to review safety-relevant processes of the operator's management system.
- Inspections of the licence holder's root cause analysis: The supervisory authority reviews the evaluation as well as the depth and completeness of the licence holder's root cause analyses to ensure that safety is continuously and actively improved.
- Inspections of the performance of safety-relevant tasks: Inspectors participate in work briefing and debriefing and in the performance of the respective tasks, e.g. periodic reviews, maintenance, radiation protection, etc., and assess how safety requirements are met and how managers at the various levels fulfil their management and supervisory duties.

The competent licensing and supervisory authority of the *Land* ensures that the licence holders apply the IMS (→ Article 13, page 96) and check, in particular, whether and how priority to safety is anchored in the basic principles of the management system. Some competent 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
- an effective review of the process under consideration is performed by the licence holder.

In addition, some of the competent 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 licensing and supervisory authorities of the *Länder* and partly by the authorities themselves. Examples of the areas in which the indicators are surveyed are event reports, false alarms, simulations, qualifications, results of inspections and ISI, 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 competent supervisory authority of the *Land* of Baden-Württemberg evaluates safety performance indicators and uses 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 been revealed 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 have adverse effects, directly or indirectly, 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.

The following procedure applies to the supervisory authority in the state of Baden-Württemberg. The inspectors collect impressions on the safety culture during the inspection activity. They evaluate what they have seen or heard on the basis of eight indicators ("quality of written documents", "cleanliness, order and maintenance of the facility", "compliance with regulations", "knowledge and skills", "working atmosphere", "workload", "performance of management tasks" as well as "interaction with the authority") and a 4-point scale ("exemplary", "in order", "not in order" and "deficiency"). As a rule, each inspector evaluates two to four indicators per inspection and documents the data in a database. In total, several hundred assessments are made per site and year. The simple software program outputs an initial data overview for further analysis by the persons in charge at the supervisory authority. The user of the software program receives, for example, the statistical values per indicator and can conclude whether there are indicators with comparatively negative or positive results. For further interpretation, the inspectors' comments, which are also documented in the database, are helpful in understanding the content of the various findings. The user also looks at the overall finding rate (percentage of "not ok" or "unsatisfactory" ratings) compared to previous years to derive possible positive trends or early warning signals of a declining safety culture. Overall, this annual evaluation combines the quantitative results of the software with the available additional (qualitative) information. The software program provides database printouts and raw statistical data, the evaluation itself requires the knowledge of a competent person. The supervisory authority presents and discusses the overall results at the annual meeting with the licence holder and discusses the reasons for weaknesses and possible improvements. Since 2016, the supervisory authority has expanded the data collection. Since then, it has been collecting impressions of the safety culture not only during on-site inspections but also during office work, i.e. in telephone calls, in the review and assessment of documents, reportable events, etc.

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 competent licensing and supervisory authorities of the Federation and the *Länder*. This principle is implemented in the task descriptions of the competent licensing and supervisory authorities, and it is concretised in supervisory practice. The competent 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 competent licensing and supervisory authorities of the Federation and the *Länder*.

Moreover, the competent 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 competent 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.

In Germany, additional internal measures of the competent 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 competent 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 competent licensing and supervisory authorities of the Federation and the *Länder* developed a common understanding of their safety culture and put it down 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 particular, the principles of the OECD/NEA on safety culture in supervisory authorities published in 2016 were applied. For the competent licensing and supervisory authorities of the Federation and the *Länder*, this results in the following principles to maintain and further develop their safety culture:

- 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.
- 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.
- The licensing and supervisory authorities maintain a culture that supports cooperation and open communication.
- The licensing and supervisory authorities pursue a holistic approach to nuclear safety and radiation protection.
- The licensing and supervisory authorities promote continuous improvement, learning, self-assessment and self-reflection at all levels.

The safety culture in the authorities of the Federation and the *Länder* has been continuously developed in a four-stage process. These stages are as follows:

- introduction to the aspects of the Statement of Principles in the supervisory authorities, e.g. through authority seminars and workshops,
- introduction to the topic “Assessment of safety culture at supervisory authorities”,
- determination of the procedure for the assessment, and
- conducting assessments.

In the third stage, the German authorities have developed processes and a set of instruments for the self-assessment of their regulatory safety culture on the basis of the common understanding of their regulatory safety culture that had already been developed. The first three stages are thus completed. Each authority is responsible for carrying out its own self-assessment. Such a self-assessment was already carried out in the review period by Directorate-General S of BMUKN beginning summer 2024 and by the Baden-Württemberg supervisory authority beginning in December 2024. In addition, there are various safety culture-specific training measures to teach and train behaviours that correspond to a strong safety culture of a supervisory authority.

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) 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), page 48). 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 holders of the licence shall be obliged to provide for and maintain permanent adequate financial and human resources to fulfil their obligation regarding the safety of the particular nuclear installation.

According to § 72(1) sentence 1 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 organising 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, page 72).

§ 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 Law on Insurance Contracts (VVG)[24].

The manner in which the availability of financial resources is secured for the decommissioning phase of a nuclear installation differs between publicly-owned installations (e.g. research reactors) and installations belonging to the private electric power utilities.

The decommissioning of publicly-owned electric power utilities is financed from the current public budget resources. For most projects, the Federation covers the bulk of the costs. Financing includes all expenses incurred for the remaining operating life, spent fuel management, execution of the licensing procedure, dismantling of facility components, and disposal of the radioactive waste (including all preparatory steps).

[24] "Gesetz über den Versicherungsvertrag (Versicherungsvertragsgesetz – VVG)", 23 November 2007; www.gesetze-im-internet.de/vvg_2008/VVG.pdf

The financial resources for installations belonging to the privately-owned electric power utilities were provided in the form of provisions built up during the operational phase. The basis for the formation of provisions in accordance with commercial law was the waste management obligation under public law derived from the AtG. The aim of the electric power utilities' decommissioning provisions was to ensure that financial resources will be available for decommissioning of the nuclear power plants after final cessation of electricity generation when there are no more revenues from electricity charges. The electric power utilities transferred the funds for storage and disposal, which follow the waste management steps of decommissioning of the nuclear power plants and the qualified packaging of the radioactive waste, to a public-law fund by 1 July 2017, the deadline for payment laid down by law, in accordance with their payment obligations pursuant to the Waste Management Fund Act (EntsorgFondsG).

Decommissioning is carried out by the electric power utilities on their own responsibility under the supervision of the competent authorities. The extent of the provisions covers all costs related to the dismantling of the power plant. These are the costs of the so-called post-operational phase during which the power plant is transferred into a state in which it can be dismantled after final cessation of power operation, the costs for licensing and supervisory procedures, as well as the costs for the dismantling. The total amount of costs is estimated based on basic studies which are regularly updated by an independent expert with due regard for technical advancements and general price trends. Information on the provisions are provided to the Federal Office for Economic Affairs and Export Control (BAFA) by the electric power utilities once a year.

The above statements apply to the commercial facilities of the nuclear fuel cycle and for waste management analogously. However, these facilities are not covered by the new provisions of the Act on the Reorganisation of Responsibility in Nuclear Waste Management, so that the provisions to be formed for this purpose must continue to also cover storage and disposal of the waste.

In all cases, staff costs are fully included in the financing, which account for 50% of the total costs and more.

The operators have set up long-term personnel programmes for the nuclear power plants under decommissioning in order to meet their safety responsibilities. New training programmes have been developed for the special requirements of decommissioning. After final shutdown and removal of the nuclear fuel, the requirements for know-how and expertise focus more on dismantling, waste management and radiation protection, while nuclear power engineering becomes less important. There are still students of engineering and radiation protection, as these subjects are also relevant in other industries and in medicine. Additional specialised knowledge for decommissioning and for the operation of the remaining safety-relevant systems such as ventilation or energy supply systems is trained on site. Maintaining a high safety culture and ensuring staff motivation are the responsibility of the operators.

Analogous to the operating phase, it is thus ensured that qualified staff is also available to the extent required during decommissioning. The high level of education and qualification in Germany is maintained through courses for achieving and maintaining the required technical qualification, education and training courses, as well as research and teaching at universities.

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 competent 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 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 executives or radiation protection supervisors. 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 supervisors at installations for the fission of nuclear fuel:
  Here, the requirements laid down in the guideline for the technical qualification according to the StrlSchV are supplemented for the radiation protection supervisors in nuclear installations. This applies to the scope of the technical qualification as well as to the acquisition and certification of the technical qualification.
- Guideline relating to the proof of the technical qualification of research reactor personnel
  This guideline specifies the requirements for obtaining a technical qualification of research reactor personnel as well as the contents of the technical and practical training. Furthermore, the guideline defines the group of persons who must provide the proof of technical qualification.
- Guideline relating to the contents of the examination of the technical qualification of responsible shift personnel in research reactors
  This guideline specifies the requirements for the contents and scope of the written and oral examination of technical qualification of responsible shift personnel in research reactors.

Staff from the authorities are present during examinations of the technical qualification. Before a person is assigned to a certain position, the licence holder has to confirm the qualification of the person with a certificate. The organisations offering training courses and the training courses are certified by GRS. The training measures and seminars offered by the licence holder are inspected by the supervisory authority. In addition to the technical training courses, courses on safety-oriented behaviour are also conducted. Qualification and training are a subject of all inspections. Experience from various decommissioning projects for nuclear installations in Germany has shown that the operating staff's knowledge of the installation is very valuable for the safe and efficient implementation of decommissioning. For this reason, the operators also involve the operating staff in the decommissioning phase.

Responsible personnel

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, among other things, 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.

An examination of the qualification follows the training to ensure that the knowledge acquired meets the requirements.

As part of technical qualification maintenance, it is ensured through various measures, 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 9, page 72).

Simulators

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

The simulators reproduced the referenced nuclear installation in appearance and also in its technical, physical and temporal behaviour. The operating staff encountered the same working conditions and requirements as they would or could have been occurred when operating and monitoring the real installation.

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

The simulator courses also included training of shift personnel in the application of emergency procedures as defined in the operator’s emergency manual (NHB). According to the “IAEA Safety Glossary: 2018th Edition”, a severe accident is an accident that is more severe than a design basis accident and involves significant core degradation. In line with the principle of giving priority to preventing core degradation over mitigating the consequences of core degradation, the emergency measures provided for in the NHB and trained on the simulators are fundamentally aimed at preventing damage to the reactor core. They are referred to as preventive emergency measures. The corresponding simulator courses concentrated on the emergency measures to be performed in the control rooms and in the remote shutdown stations. They did not include accident conditions with core degradation. According to § 7c(3) AtG, the licence holder is required to ensure the operability of the emergency measures also for mitigative emergency management by maintenance and ISIs and to conduct the measures periodically in exercises. Therefore, regular emergency exercises – partly with the support of simulators – took place with the crisis management team.

Knowledge maintenance

With regard to decommissioning, it is necessary to maintain the expertise required for decommissioning in order to ensure the safe dismantling of the plants. 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 and the recruitment of young scientists in nuclear technology. BMFTR 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 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 appropriate fulfilment of departmental tasks. It thus also contributes to the general gain in knowledge. The research framework of the ministries is concretised annually by individual research and development projects. These are part of the research plan of BMUKN on the basis of which the research funds are managed.

With regard to operating experience, various instruments exist in Germany for the maintenance or exchange of knowledge. These are databases, research projects, web-based information portals/web pages, regular discussions in expert commissions and in the *Länder* Committee for Nuclear Energy, seminars and workshops of the technical safety organisations etc.

Supervision

As part of the licensing and supervisory procedure, the competent licensing and supervisory authority has to verify compliance with all guidelines listed above. This is done on the basis of regular proofs to be provided by the licence holder. Within the framework of the technical qualification examinations, this is ensured by the participation of staff of the competent 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 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 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, page 87). Since the 13th AtGÄndG, 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 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 SiAnf stipulate 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. These general requirements include

- 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, and
- reliable monitoring of the operating conditions that are relevant in the respective operating phase.

In addition, the SiAnf 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 safety standards of the KTA:

- Safety standards KTA 1201 “Requirements for the Operating Manual”, KTA 1202 “Requirements for the Testing Manual” and KTA 1203 “Requirements for the Emergency Manual” contain the requirements for the respective manuals (→ Article 19 (iii), page 170).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.
- Safety standards KTA 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, page 113) 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.
- Safety standard KTA 1402 “Integrated Management System for the Safe Operation of Nuclear Power Plants” defines in detail the components of an IMS (→ Article 10, page 78 and Article 13, page 96), 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 (Safety standard KTA 1402, Section 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 (Safety

standard KTA 1402, Section 4.1.5). With regard to the number of staff and staff qualification, sufficient capacities shall also be provided in the long term (Safety standard KTA 1402, Section 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 (Safety standard KTA 1402, Section 5.5).

- 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 safety standards of the KTA 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, the following recommendation was issued by the 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"[25]
  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 RSK recommendation on requirements on the determination of the minimum shift staffing at nuclear power plants to ensure safe operational management is based, among other things, on the method of analysing the required minimum shift staffing on a plant-specific basis. The determination of the minimum shift staffing is based on all tasks of the operating staff specified in the operating documents. Event sequences can be used for the analysis that are defined on the basis of conservative assumptions. The analyses for determining the minimum shift staffing are to be documented in a comprehensible manner. When determining the minimum number of shift staffing, it is to be ensured that sufficiently qualified operating staff are available both for the performance of safe normal operation and for the control of events on levels of defence 3 and 4 until the safe arrival of support staff. Staff on standby or emergency organisation staff may be taken into account in the analyses if they will be ready in time.

Section 3.7 of the Guide to the decommissioning, safe enclosure and dismantling of facilities or parts thereof as defined in § 7 AtG[26] contains the requirement that the operator has to ensure *"that an*

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[25] RSK recommendation on requirements on the determination of the minimum shift staffing at nuclear power plants to ensure safe operational management ("Anforderungen an die Bestimmung der Mindestschichtbesetzung in Kernkraftwerken zur Gewährleistung einer sicheren Betriebsführung"), 417th meeting of the RSK on 18 June 2009; www.rskonline.de/sites/default/files/reports/epanlagersk417hp.pdf

[26] "Leitfaden zur Stilllegung, zum sicheren Einschluss und zum Abbau von Anlagen oder Anlagenteilen nach § 7 des Atomgesetzes", 16 September 2021; 16: September 2021; www.base.bund.de/SharedDocs/Downloads/BASE/DE/rsh/3-bmub/3_73.pdf?__blob=publicationFile&v=1

adequate number of staff with the required qualification and knowledge is available in all phases and periods of the decommissioning project until release from regulatory control under nuclear and radiation protection law. The use of own staff as responsible persons in terms of the technical qualification guideline is to be maintained with regard to the preservation of plant-specific knowledge and in compliance with the responsibility and control obligations. According to § 7(2)1 AtG, the responsible persons must have the required technical qualification. Persons otherwise engaged in the decommissioning measures must possess the necessary knowledge as defined in § 7(2)2 AtG. The organisational structures necessary for safety must be ensured."

Decommissioning and dismantling licences have meanwhile been granted for all German nuclear installations (→ Appendix 1-1, page 185). The regulatory framework includes a lessons learned process from the licensing procedures. Experience from the above-mentioned licensing procedures shows that the regulatory framework and the licensing procedures for decommissioning are currently robust even for several licensing procedures carried out in parallel. Experience decommissioning project accompaniment shows that a high level of safety is achieved. In order to maintain this high level of safety under the given circumstances (German phase-out decision and a relatively high number of nuclear decommissioning projects carried out in parallel), the necessary staff with the required qualifications must be maintained at all levels (operators, federal and *Land* authorities and transmission system operators). Germany recognises and is addressing the potential challenges related to the management of the required qualified workforce, which may increase in the future.

Currently, 33 decommissioning projects in different phases are carried out in parallel in Germany.

At the operator's level, qualified personnel for decommissioning means, on the one hand, technically qualified personnel, e.g. for remote dismantling activities, material handling, radiation protection and waste management, including waste documentation. On the other hand, the number of qualified workers required by the technical qualification guideline must be complied with. For this purpose, the operators qualify their own personnel, but also external companies in the long term (→ Article 11(1), page 85).

During the development process of the "Concept for Competence Building and the Development of Future Talent for Nuclear Safety", needs/demand analyses were carried out in order to plan specific measures in advance. The needs/demand analyses were carried out stepwise, starting with the identification of needs at the federal level (BMUKN, BASE, BfS, BGE, BGZ). In a second step, needs outside the federal level (e.g. *Länder*, advisory bodies, specialised organisations, associations) were determined. The analyses also took into account the need for qualified personnel for the high number of decommissioning projects in the nuclear sector. The "Strategy for Competence Building and the Development of Future Talent for Nuclear Safety" identifies various areas of action on which measures to maintain and build expertise and specialist capacities should be focussed. The first area of action is education and teaching. Professional qualifications are the key to the long-term preservation of knowledge and the recruitment of skilled personnel. Another area of action is research and development. Ongoing state-funded research and development is essential in order to maintain and further develop technical and scientific expertise in the dynamically developing fields of nuclear safety during decommissioning in the long term.

The staff of the nuclear licensing and supervisory authorities are generally civil servants appointed for life. The working conditions, e.g. compatibility with the demands of family life, and the salary are quite attractive. It is therefore possible to employ competent young people with university degrees in the relevant areas. In the field of decommissioning supervision, they have employment prospects of around 20 years. In other supervisory areas such as waste storage or radiation protection in industry and medicine, attractive jobs will also be available in the future. Due to the permanent civil servant status, the interesting work and the long-term prospects in the broad field of radiation protection, the conditions are good for attracting new staff in the future.

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. With regard to maintenance, especially as concerns ISIs, technical measures are provided to prevent human errors or to minimise their effects.

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 exposure is consequently 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.

The operators of nuclear installation use a so-called work permit procedure to carry out any activities in the installation. In the associated work permit note, the affected rooms and parts of the installation are clearly defined. In addition, possible retroactive effects on other systems and equipment are taken into account when drawing up the work permit. A prerequisite for carrying out activities is their approval by the persons responsible for them. During this process, among other things, operating data and valve positions are checked. Before activities are carried out, release switching is checked on site (operating parameters and valve position). For activities in the controlled area, the radiation protection parameters are also taken into account by means of a special radiation protection certificate. Important here are the local dose rates in the room and at the structure, system or component where the activities are carried out. Depending on the dose rate measurements, radiation protection measures, such as shielding, are carried out. Radiation protection personnel accompany the activities with on-site measurements so that a rapid response can be made in the event of deviations.

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 (→ Article 10, page 78 and Article 13, page 96) and 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 ensure 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 the events at the plant are assessed and, if necessary, evaluated as part of a root cause analysis (root cause analysis, → Article 7 (2iii), page 48 and Article 19 (vii), page 177). The selection of events for which a root cause analysis is performed is based on predefined criteria such as safety significance, personal injury, complexity of the event sequence, relevant contributions of acting persons in the course of the event (human factors) or relevant problems in the cooperation of different organisational units (organisational factors). The aim of this analysis is to learn from operating experience gained and to derive safety-related improvements. To achieve this, the areas of MTO are treated equally. The analysis also looks at weak points and failure sources at the interfaces of the three areas. This integrated approach makes it principally possible to identify the factors that have led to an event. The analysis includes amongst others the reconstruction of the event sequence, the analysis of deviations from the expected sequence, the identification, analysis, and evaluation of factors that contributed to the event, the derivation and implementation of corrective actions, and the evaluation of their effectiveness. On this basis, measures are then developed to eliminate identified sources of error. In 2000, the licence holders began developing the VGB guideline on root cause analyses (VGB-Leitfaden “Ganzheitliche Ereignisanalyse”), which was presented for the first time in 2003. In 2014, the RSK has developed a guideline for the performance of root cause analyses, which has been applied by the German licence holders of nuclear installations after consultation with the vgbe since 2015.

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 licensing and supervisory authority of the *Land* in the form of an information notice (WLN) prepared by GRS on behalf of BMUKN (→ Article 19 (vii), page 178). 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 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.

The RSK regularly deals with reportable events in the field of man and organisation, also in the form of presentations of the operators on the results. For this purpose, it prepares generic recommendations. In recent years, one focus has been on evaluating the effectiveness of measures to prevent recurrent events, such as those derived from a root cause analysis. These recommendations are published and considered by the competent 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 (→ Article 10, page 78 and Article 13, page 96) whose requirements are described in the SiAnf and in safety standard KTA 1402 “Integrated Management Systems for the Safe Operation of Nuclear Power Plants”. 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 licensing and supervisory authority of the *Land* through various supervisory activities (e.g. on-site supervisory inspections on the root cause analysis and on organisational topics). This was 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 licensing and supervisory authority. Any later modifications to safety-relevant plant components and written operating rules (e.g. the operating manual or testing 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 follow-up to modifications, the effectiveness is checked in the supervisory procedure. The supervisory authority can choose different approaches. First, the authority may review the operator's effectiveness evaluation, i.e. the methodology of the evaluation, the results and the measures derived. In addition, the supervisory authority may conduct separate supervisory evaluations of the effectiveness of previous organisational changes, either in the form of specific supervision or as part of other regular supervision. For example, the regulatory officials may interview those responsible for the change and those affected by the change about their perceptions of the impact of the change and the accompanying measures. In this way, the licensing and supervisory authority can review findings (e.g. dissatisfactions) that affect the organisational change. Furthermore, the authority checks the fulfilment of additional requirements specified in the regulatory approval of the organisational change, e.g. with regard to staffing and training.

Independently of the review of the effectiveness of individual organisational changes, the authority holds regular meetings with plant management to discuss issues such as strategies, long-term modifications and their gradual implementation, staff motivation (e.g. openness to new tasks, staff turnover rates, reasons for departures, challenges in recruiting staff), know-how planning and human resources planning.

In the assessment of reportable events and other occurrences, the competent 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) 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 SiAnf. There, the implementation of an IMS (→ Article 10, page 78) is required for all nuclear installations. This covers all core, cross-sectional and strategic processes required for operation. Based on a process model, the IMS describes all internal regulations and processes that are necessary to achieve the objectives of the facility and takes into account the aspects of safety, quality, environmental protection, energy, health and occupational safety as well as economic efficiency and quality assurance in accordance with the nuclear rules and regulations. The management system is bindingly regulated in the management system description. Procedural guidelines, procedural instructions and implementation instructions are used as descriptive documents. This organisational documentation is structured in the form of a pyramid and thus includes all organisational documents and refers to existing manuals, such as the BHB, the testing manual and other regulations.

The objectives and requirements of the IMS also include quality assurance. This is specified within the framework of the national nuclear rules and regulations, especially in the safety standards of the KTA, as follows:

- Safety standard KTA 1401 “General Requirements Regarding Quality Assurance”
  This safety standard of the KTA 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 safety standard 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 safety standard of the KTA 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. Safety standard KTA 1402 came into force in 2012, was revised in 2017 and declared to remain valid for five more years in 2022. 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.
  Safety standard KTA 1402 is supplemented by several related safety standards of the KTA. All safety standards of the KTA related to safe operation (safety standards KTA 1201, 1202, 1203, 1401, 1402 and 1403) should be considered together. In fact, this is stated in safety standard KTA 1402, “Basic Principles” (5), which explicitly mentions all standards mentioned above.

In addition, DIN EN ISO 9001:2015[27] 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.

The basic requirements for a quality management system according to DIN EN ISO 9001:2015 are also applied to products or services which are no longer subject to the safety-related requirements of safety standard KTA 1401 with regard to quality requirements and characteristics as far as they are necessary for the availability and reliable operation of the facility. In this case, contractors and subcontractors must demonstrate that their quality management system is certified in accordance with DIN EN ISO 9001:2015. Requirements for mechanical engineering components that go beyond DIN EN ISO 9001 are laid down in special nuclear specifications.

Alternative regulations for the quality management system and its certification are possible as far as they fulfil the requirements of safety standard KTA 1401 (No. 1(3) and 3(5)) for an effective quality management system and enable the verification (certification). In those cases where a contractor does not fulfil individual requirements of this safety standard (KTA 1401, 3(6)), the client shall specify and document suitable substitute measures. This can be, for example, a special quality assurance plan which is prepared by the contractor as a substitute measure in individual cases and approved by the power utility and, if necessary, by expert bodies – depending on the safety requirements. For products and services which are no longer subject to the requirements of safety standard KTA 1401, other, possibly specific, industry standards are applied, e.g. the AD2000 safety standards or DIN EN standards.

The most effective way to ensure the long-term quality of products and services is through a continuous, closed overall process.

Particularly important measures include the development and definition of specifications for design and quality at the beginning and the consistent comparison until the end of the installation phase, including the associated technical documentation as well as the audit programmes and contractor assessments.

Elements of the integrated management system (IMS)

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.

GRS monitors international activities on non-conforming, counterfeit, fraudulent, or suspect items (NCFSI) on behalf of BMUKN. GRS actively participates in the NCSFI working group of the OECD/NEA Expert Group on Operating Experience (EGOE). According to the current state of knowledge, the German rules and regulations on quality assurance throughout the entire manufacturing process seem to be sufficient to prevent significant NCFSI problems. Regulatory inspections and audits of the quality assurance system of the licensees are carried out on a regular basis. Plant visits by the supervisory authorities in the case of important manufacturing processes (witnessing) and regulatory inspections of the related documentation are carried out as regular tasks within the framework of regulatory supervision.

In some of these cases, BMUKN requested additional information from the facilities via the *Land* authorities. For example, deliveries of suspect items or from suspect manufacturers were checked by the operator. Due to the strict quality assurance processes required in Germany, no relevant

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

incidents are known from operational practice. Therefore, no further specific measures were taken against NCFSI.

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 helps 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, page 78).

Each licence holder already had to meet individual specific quality assurance requirements on the basis of the provisions of the SiAnf of 1977. In 2012, the safety criteria were replaced by the newly developed SiAnf. 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 license 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.

According to DIN EN ISO 9001, process-orientated quality assurance is also geared towards a continuous improvement process for the further development of processes, products and services. The organisation must constantly review and improve the effectiveness of the quality management system. One concept for this is, for example, the application of the PDCA cycle to management systems and their processes. Through repeated application and from the results, the organisation learns to identify the causes of errors and to implement effective remedial measures to further develop the management systems.

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 vgbe 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 competent licensing and supervisory authorities pursue the following topics of the management system or obtain information about them:

- results of the management review,
- results of the internal audits,
- evaluation of indicators (→ Article 10, page 80),
- implementation of measures derived,
- further development of the IMS, and
- promotion of safety culture through various human performance optimisation measures (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 vgbe 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 (→ Article 3, page 98) 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 the dismantling of the installation.
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.

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

The authorisations for power operation of the German nuclear power plants have expired. Decommissioning and dismantling licences have been issued for all nuclear power plants in accordance with § 7(3) AtG. If the operating licence is not completely revoked with the decommissioning licence, the unamended conditions and regulations of the operating licence remain in force.

According to § 7(2) 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, and if
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 SiAnf, their “Interpretations” and the safety standards of the KTA (→ Article 7 (2i), page 41).

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 licensing and supervisory authority that the licence prerequisites stated in § 7(2) AtG (→ Article 7 (2ii), page 44) are fulfilled. § 3 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 as well as decommissioning and dismantling, 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 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 (including beyond-design-basis accidents).

Except for the limits and conditions 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. The emergency organisation is described in the NHB, which is required according to safety standard KTA 1203 “Requirements for the Emergency Manual”. In Germany, the limits and conditions of safe operation are part of the BHB. Furthermore, information on the future decommissioning of the nuclear installation is also required in the safety analysis report. For the assessment of the current safety status of the installation in the post-operational phase, the following is to be taken into account:

- the assessment of events relevant for the post-operational phase,
- the assessment of the safety-relevant systems in the post-operational phase, and
- other aspects such as decontamination, handling procedures, availability of equipment and systems of the planned safety measure.

Details on precautions to protect 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 competent 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, a 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.

For the decommissioning and dismantling licence, a safety report with an analysis of safety-relevant measures is required among other things. There are no further requirements for the safety analysis in the post-operational phase apart from the List of Contents.

Safety assessments in the supervisory procedure

Safety assessments are submitted to the competent 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), page 44).

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), page 157).

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), page 44). As regards modifications of the nuclear installation or its operation that are not subject to licensing pursuant to § 7 AtG due to 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 competent licensing and supervisory authority and which modifications the licensing and supervisory authority only has to be notified.

After any safety-relevant event at a nuclear installation, the competent 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 plant security. 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 competent 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 nuclear installation. The last SÜ of the three German nuclear installations that were last shut down was carried out in 2009. The obligation to present the SÜ results is lifted if the licence holder makes the binding declaration to the competent licensing and supervisory authority that he is definitively going to terminate power operation no later than three years after the final date for submission of the SÜ mentioned in the AtG. The three nuclear installations whose lifetimes were extended at short notice until 15 April 2023 had made use of this regulation. However, it would not have been possible to carry out the SÜ and, in particular, to implement safety improvements in the short time available (→ Article 6). Nevertheless, the obligation to continuously improve the installation in accordance with the advancing state of the art in science and technology pursuant to § 7d AtG always applies, irrespective of the SÜ intervals.

For the nuclear installations in post-operation, the General Committee of the 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.

The installations under decommissioning are not subject to an SÜ within the meaning of the AtG. "In the case of immediate dismantling, the supervisory authority conducts safety reviews at least every ten years depending on the hazard potential of the nuclear facility. In this context, the results of reviews within the framework of nuclear licensing or supervisory procedures of the last ten years are taken into account. The authority determines the scope of the safety review depending on the condition of the facility. […] Kind and scope of the safety reviews to be conducted periodically during safe enclosure (at least every ten years) are to be specified in the decommissioning licence."[28]

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), page 157).

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), page 157) are in place.

Probabilistic safety analyses (PSAs)

In Germany, the PSA was introduced in the mid-1970s to supplement the deterministic safety assessment. A revision of the PSA guidelines is no longer planned, since no SÜ, which PSAs were part of, were required for any of the nuclear installations that were still in operation within the review period.

The methods and data to be used for the PSA are described in a guide[29] and in supplementary technical documents (methods and data for probabilistic safety analysis for nuclear power plants[30,31,32]) These were first published in 1996 and updated in 2005 and 2016. The latest update contains amendments and updates to the following subject areas, which have already been included since the update in 2005 and that are to be taken into account according to the state of the art in science and technology:

- Level 2 PSA,
- PSA for low-power and shutdown modes,
- consideration of the human factor in a PSA,
- PSA for external hazards, and
- 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).

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28 "Leitfaden zur Stilllegung, zum sicheren Einschluss und zum Abbau von Anlagen oder Anlagenteilen nach § 7 des Atomgesetzes"; 16: September 2021"; www.base.bund.de/SharedDocs/Downloads/BASE/DE/rsh/3-bmub/3_73.pdf?__blob=publicationFile&v=1

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

30 "Methoden zur probabilistischen Sicherheitsanalyse für Kernkraftwerke", BfS, BfS-SCHR-37/05, ISBN: 3-86509-414-7, August 2005

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

32 "Methoden und Daten zur probabilistischen Sicherheitsanalyse für Kernkraftwerke", BfS, BfS-SCHR-61/16, September 2016

A further supplementary technical document (methods and examples for the probabilistic assessment of safety-relevant issues outside the SÜ[33]) was published in 2018. It contains methodical guidance and recommendations for the implementation of the SiAnf 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 exist for all nuclear installations in power operation during the review period. 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.

Backfitting measures and improvements performed and current activities

The dismantling of the German nuclear installations was licensed on the basis of current regulations and findings.

After the final shutdown of the plants, no further safety-relevant improvement potentials were identified that would have required corresponding backfitting measures.

Accident mitigation manual (HMN)

The licence holders of German nuclear installations also developed a generic concept for the management of severe accidents in the form of an 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 had been introduced in all nuclear installations in power operation.

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

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[33] "Methoden und Beispiele für die probabilistische Bewertung sicherheitsrelevanter Fragestellungen außerhalb der SÜ", BfE, BfE-SCHR-03/17, February 2018

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[34].

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 competent licensing and supervisory authorities of the *Länder* review the safety assessments carried out by the licence holders. The resulting findings on necessary safety improvement measures or backfitting measures are implemented by the licence holders if a substantial improvement in safety can be achieved. Due to the low radiological risk potential during decommissioning, this is more of a hypothetical scenario.

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), page 61). 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 evaluated. The persons participating in the evaluation are free in their judgement and are mentioned by name to the competent licensing and supervisory authority.

14 (ii) Verification of safety

Due to the discontinued use of nuclear energy for the commercial generation of electricity in Germany (power operation of nuclear installations), some Convention articles relating to the power operation of nuclear installations are no longer relevant for Germany. The contents of this sub-chapter largely describe the procedure for power operation.

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 competent 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, ISIs 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

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[34] 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

testing manual according to safety standard KTA 1202 "Requirements for the Testing Manual", which, in their relevant parts, also have to be applied during decommissioning procedures.

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 ISIs 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 ISIs 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), page 177).

The ISIs of safety-relevant systems are performed in accordance with the requirements specified in the testing manual (→ Article 19 (iii), page 168). 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, 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. Typical for a nuclear power plant with PWR were about 3,500 ISIs during operation and an additional 1,000 during a refuelling outage.

Apart from the ISIs of safety-relevant systems and components, the licence holders perform additional ISIs under their 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 ISIs, maintenance and servicing measures. Possible problems are identified in advance and preventive measures are taken in due time. Currently, there are no findings from ageing monitoring that would require modifications. At its 512th meeting on 22/23 October 2019, the RSK dealt with the results of the ENSREG Topical Peer Review (TPR) on ageing management and concluded that the German nuclear power plants would not require any further examinations on the RPV material. 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 competent 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 safety standard of the KTA 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 scope of application of the safety standards of the KTA is limited to operational issues. Safety standard KTA 1403 applies to the ageing management procedures in connection with safety-related systems and equipment, including the associated auxiliary and operating equipment, specified in the licensing documents and operating instructions of light water reactors in operation. However, the requirements of safety standard KTA 1403 may also be applied in the decommissioning stage according to a graded approach.

The licence holders have set up IMSs 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 maintenance measures of ageing management are carried out preventively. This is done as predictive maintenance or condition-based maintenance. Predictive maintenance takes place at specified intervals. It is the most frequently applied type of maintenance for SSCs. For condition-based maintenance, inspection and diagnostic procedures are used at regular intervals, which make it possible to make a statement about the condition of the components. The inspection intervals are then adjusted individually depending on the condition. Inspections of active safety-relevant components are generally carried out on the basis of maintenance instructions with component-specific specifications such as test and inspection plan, dimensional record sheet, specifications for threaded joints and lessons learned and other relevant documents. This ensures that tests and inspections are carried out in the required quality.

The basic requirements for carrying out maintenance measures and ISIs are laid down in the operating licences of the installations, the operating manual and the testing manual. The boundary conditions with regard to both the technical issues and the procedures for effective ageing management are thus clearly defined in the licensing documents of the installations. In the event of findings (failures, faults or deviations from the nominal condition), measures (repair, replacement, etc.) are generally taken to restore the specified condition (quality). In case of relevant findings, appropriate measures (maintenance, assessment, inspection, repair) are also carried out on comparable components in order to exclude common mode failures. Since ageing degradation mechanisms often develop slowly over time, trend analyses of long-term behaviour can be carried out on the basis of the evaluation of the measurement data and possible degradation developments on SSCs can be detected at an early stage. Within the framework of ageing management, the reports on maintenance, repairs, failures and faults of the SSCs are regularly checked for relevant ageing phenomena. In addition, the maintenance, repair, failure and fault reports of all other non-safety-relevant components and systems are evaluated.

The procedure described was presented in detail in the German report on the TPR of the EU on ageing management in nuclear installations and explained using examples. In the report of the

ENSREG on the results of the TPR, two “good practices” and three “good performances” are highlighted for Germany. These concern participation in international cooperation in ageing management, the design of RPVs to reduce neutron embrittlement, the consideration of medium influences in fatigue analyses and the test concept for inaccessible pipelines.

The selection of suitable testing techniques is based on the national nuclear rules and regulations with the testing techniques specified therein (e.g. Table 2-1 in safety standard KTA 3211.4). The aim is to ensure the required quality for ongoing operation and to prevent extensive failure of pipe walls. The selection also depends on the coating and the possible degradation mechanism. For pipes of the same design (material, diameter, wall thickness, covering, operating parameters, etc.), an appropriate test method may be to test pipes from the outer wall side (if accessible) and to transfer the results to inaccessible pipe sections.

Potential for improvement was identified in four areas (“areas for improvement”). These were taken into account in the National Action Plan for the TPR[35].

Measures for internal reviews of the licence holders

World Association of Nuclear Operators (WANO) peer reviews

Until the final shutdown of German nuclear installations, the licence holders, as members of WANO had 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 were reviewed and assessed by international experts on a mutual basis. The reviews also served 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 was to improve operational performance in terms of reliability and safety. A review of the implementation of selected optimisation measures was carried out in follow-up reviews.

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

Reviews within the framework of state supervision

The competent 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 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.

In the LAA, there is a mutual exchange of information in the specific technical committees and the associated working groups between the licensing and supervisory authorities of the *Länder* and the Federation. In addition, the authorised experts consulted prepare reports of anomalies, of which those of general relevance are submitted to BMUKN, which informs the other *Land* authorities.

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[35] “National Action Plan”, Report by the BMU on Topical Peer Review Ageing Management of Nuclear Power Plants and Research Reactor, September 2019, www.bmuv.de/en/download/first-topical-peer-review-tpr/

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 competent licensing and supervisory authority in order to monitor compliance with the provisions of the licence provisions and of the supervisory procedure. These accompanying inspections, intended to verify the values, dimensions or functions specified in the submitted written documents, were independent of the manufacturer's tests. This included e.g. the verification of material compositions at the manufacturers site, controlling the assembly of components and the performance of functional tests. Similar inspections were 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 were checked (→ Article 19 (i), page 166). In case of modifications, the procedure is analogous.

Inspections within the framework of regulatory supervision

The competent 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 competent 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
- plant security.

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 staff.

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 MTO in the way they interact.

The ISIs carried out by the licence holder on safety-relevant components are accompanied by authorised experts of the competent 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 competent licensing and supervisory authority and authorised experts on site want to form their own opinion on the findings made.

The licence holders are required, e.g. by licensing requirements, to submit written reports on various topic areas. These include e.g. matters relating to operation, safety and radiation protection including environmental monitoring, the inventory and whereabouts of radioactive materials as well as plant security. The competent 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 competent licensing and supervisory authority of the *Land* or a subordinate authority with the help of KFÜ (→ Article 15, page 127). 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 competent 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" had 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 § 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.

The German nuclear installations maintained or improved their safety level through continual backfitting until cessation of power operation.

For nuclear installations that were 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 StrlSchG and the 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 for occupationally exposed persons. 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 laid down in radiation protection law for annual effective doses, organ equivalent doses and lifetime doses are summarised in Table 15-1.

Requirements for the protection of workers

In § 78(1) sentence 1 StrlSchG, a maximum effective dose of 20 mSv per calendar year is defined as the limit for the body dose of occupationally exposed persons. According to sentence 2, the competent licensing and supervisory authority may permit an effective dose of 50 mSv (or organ equivalent dose of the eye lens of 50 mSv) in a single year in individual cases, 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 (§ 78(3) StrlSchG). For the occupational lifetime dose, a limit of 400 mSv is set for the effective dose in § 77 sentence 1 StrlSchG. Exposure to this limit corresponds to an increase in the lifetime cancer risk by a total of around 4%. The competent authority may, in consultation with an authorised physician, permit additional occupational exposure if this does not exceed 10 mSv and the occupationally exposed person consents (§ 77 sentence 2 StrlSchG).

In emergency situations, according to § 114(1) StrlSchG, the aim shall be to keep the exposure of emergency workers below the values specified in § 78 StrlSchG for occupationally exposed persons. 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 to save lives, prevent serious radiation-related health damage or prevent or combat a disaster (§ 114(3) sentence 2 StrlSchG).

Table 15-1 Limits and reference levels for body doses according to StrlSchG and StrlSchV

§	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, averaged over any area of skin measuring one square centimetre irrespective of the exposed area (local skin dose)	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
	Effective dose for an unborn child (due to occupational activity of the mother)	Pregnancy	1
	On a case-by-case basis after approval by the competent authority		
	Effective dose	Calendar year	50
	Organ equivalent dose: eye lens	Calendar year	50
§ 74 StrlSchV	Specially permitted **exposures** in exceptional circumstances (only voluntary adults of Category A; no pregnant women, no trainees and students, breast-feeding women only if incorporation/contamination is excluded; only after approval by the authority)		
	Effective dose	Occupational life	100
	Organ equivalent dose: eyes lens	Occupational life	100
	Organ equivalent dose: hands, forearms, feet and ankles	Occupational life	1000
	Organ equivalent dose: skin (local skin dose)	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 (local skin dose)	Calendar year	50
	Organ equivalent dose: hands, forearms, feet and ankles	Calendar year	50
	On a case-by-case basis after approval by the competent authority		
	Effective dose: for trainees and students from 16 - 18 years	Calendar year	6
	Organ equivalent dose: skin, hands, forearms, feet and ankles	Calendar year	150
Dose limits for members of the public			
§ 80 StrlSchG	Effective dose	Calendar year	1
	Organ equivalent dose: eyes lens	Calendar year	15
	Organ equivalent dose: skin (local skin dose)	Calendar year	50
§ 99 StrlSchV	**Dose limits for discharges to air and discharges to water**		
	Effective dose for each discharge path	Calendar year	0,3
§ 104 StrlSchV	**Accident planning levels for nuclear installations**		
	Effective dose	Event	50
	Organ equivalent dose: thyroid	Event	150

§	Scope of applicability	Time period	Dose [mSv]
	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 emergency operations, the aim shall be to ensure that the dose limits (reference levels) corresponding to the limits for occupationally exposed persons pursuant to § 78 StrlSchG are not exceeded. Only if this is not possible with reasonable effort may the following higher reference levels apply for specific purposes:		
	• Emergency operation serves to protect life or health (no pregnant women or persons under 18 years of age)	Emergency event	100
	• Emergency operation serves to save lives, prevent serious radiation-related health damage, or prevent or respond to a disaster (volunteers only, no pregnant women or persons under 18 years of age).	Emergency event	250
	• Emergency operation serves to save lives, prevent serious radiation-related health damage, or prevent or respond to a disaster in exceptional cases (volunteers only, no pregnant women or persons under 18 years of age).	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 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.

According to § 71(1) StrlSchV, 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 per calendar year, an organ equivalent dose higher than 15 mSv per calendar year for the eye lens or 150 mSv per calendar year for skin, hands, forearms, feet and ankles are classified as Category A (§ 71(1)1 StrlSchV). 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 licensing and supervisory authority (§ 77 StrlSchV). For 2023, dose reports from 95,691 occupationally exposed persons in Category A and 337,233 occupationally exposed persons in Category B were submitted to the Radiation Protection Register.

Moreover, a radiation passbook is to be maintained in accordance with § 68 StrlSchV for persons working in foreign radiation protection areas. The same applies to persons who carry out corresponding activities outside a radiation protection area if these activities can lead to an effective dose of more than 1 mSv per calendar year. Specifications for the radiation passbook are laid down in § 174 StrlSchV and the general administrative provision on the radiation passbook (AVV Strahlenpass). 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.

For dose reduction and avoidance of unnecessary exposures, § 72(1) sentence 1 StrlSchV provides for an examination by the licence holder as to whether the establishment of dose constraints for occupationally exposed persons is a suitable instrument for optimising radiation protection. The establishment of dose constraints is to be included in the planning of operational radiation protection in particular if the respective activity is associated with exposures that require the occupationally exposed persons to be classified in Category A and for which the optimisation of radiation protection is not already ensured by other measures of radiation protection planning. Other measures that ensure the optimisation of radiation protection are, in nuclear technology, in particular the requirements of the Guideline concerning the radiation protection of personnel during maintenance, modification, waste management and dismantling work in nuclear installations and facilities, Part 2: Radiation protection measures to be taken during the operation or decommissioning of an installation or facility (IWRS II) as well as the specification of daily reference levels within the installation, which, if exceeded, lead to a review of the work situation as specified in the subordinate rules and regulations by safety standard KTA 1301.2 “Radiation Protection Considerations for Plant Personnel in the Design and Operation of Nuclear Power Plants. Part 2: Operation”. According to 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, these provisions are also to be applied throughout the decommissioning stage, taking into account the current condition of the facility and the hazard potential.

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 and decommissioning (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 competent supervisory authority.

In general, the basic ideas of the ALARA principle are included in the licence holders’ radiation protection measures. The ALARA principle is reflected, for example, in

- 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 legal requirements together with the increased radiation protection awareness among the personnel and the involvement of the competent 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 or decommissioning stage. This measure allows to permanently reduce the exposure of personnel during the planned activities.

Requirements for the protection of the public

Exposure of the public during 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 StrlSchV.

Any radioactive discharge with exhaust air and wastewater is recorded nuclide-specific according to type and activity, thus allowing 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 (AVV) regarding §§ 100 and 101 StrlSchV on the “Determination of the exposure of individuals of the population due to activities subject to licensing or notification”. According to this, the exposure for a representative person is to be calculated for all exposure pathways at the most unfavourable receiving points such that the exposure to be expected will not be underestimated (Section 3. 1 on objectives and principles for determining exposure of the aforementioned AVV).

Exposure of the public in the event of design basis accidents

As part of the licensing procedure, the applicant must demonstrate by means of a radiological consequence analysis that the dose limits (among others 50 mSv per event for the effective dose, → Table 15-1) will not be exceeded in the event of a design basis accident. However, this does not cover all possible accidents or emergencies. In the event of a radiological emergency (→ Article 15, page 117), the accident planning levels may be exceeded.

According to § 104(3) StrlSchV, structural and technical protective measures are to be taken for decommissioning projects in accordance with § 7(3) AtG, taking into account the potential extent of damage, in order to limit exposure in the event of design basis accidents. The licensing authority determines the type and scope of the protective measures, taking into account the individual case, in particular the hazard potential of the facility and the probability of occurrence of a design basis accident. According to § 104(6) StrlSchV, the protection goals for the prevention of accidents are to be specified by general administrative provisions. Until these come into force, an accident planning level for the effective dose of 50 mSv applies, as stipulated in § 194 StrlSchV. Some of the safety assessments (accident analyses) already carried out for the construction and operation of the facilities under decommissioning can still be used. As long as there is still nuclear fuel exceeding the masses or concentrations specified in § 2(3) AtG in the facility during decommissioning, all necessary safety precautions must continue to be observed and included in the corresponding considerations.

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 (e.g. establishment of emergency organisations within the facility or provision of emergency power generators) in order to control design extension conditions or at least to mitigate their consequences inside and outside the installation (→ Article 18 (i), page 157). 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, page 128) if there are significant releases or the risk of such releases.

Emission and immission monitoring

Maximum permissible activity amounts and concentrations for the discharge of radioactive substances are defined by the competent licensing and supervisory authorities within the framework of the procedure for granting an operating and decommissioning 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, page 114). Together with the contribution by direct radiation, the limits of § 80 StrlSchG (→ Table 15-1, page 114) 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 licence (ALARA principle). Thus, for example, high demands were 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),
- Safety standard 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”,
- Safety standard KTA 1503.2 “Part 2: Monitoring the Discharge of Radioactive Matter with the Vent Stack Exhaust Air During Design-Basis Accidents”,
- Safety standard KTA 1503.3 “Part 3: Monitoring the Non-stack Discharge of Radioactive Matter” and
- Safety standard 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 licensing and supervisory authorities. In support of the competent licensing and supervisory authorities, BfS carries out control measurements and informs these authorities of the measuring results. The quality of the control measurements is ensured by comparative measurements and comparative analyses with the licence holder.

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 wastewater 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 competent 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 competent licensing and supervisory authorities whose data are transmitted online via the 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 competent licensing and supervisory authority. In addition, measurements are performed by independent measuring institutions on behalf of the competent 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, during decommissioning, during a safe enclosure period and the dismantling of facilities 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. Monitoring during decommissioning, safe enclosure and dismantling is to be carried out as long as nuclear fuel, fission or activation products are still present in these facilities and emission of radioactive substances or exposure due to direct radiation are possible. The scope of the measurements is initially based on the measurements during specified normal operation. It can be adjusted by the competent authority according to the type and activity of the radioactive substances remaining in the facility, taking into account their possible effects on the environment. 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 or during decommissioning, safety enclosure and dismantling and can be determined in the event of a design basis accident or emergency. The results of immission monitoring are submitted to the competent licensing and supervisory authority and are centrally recorded, evaluated and published by 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 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 wastewater from nuclear installations. The values are mostly below 100 Bq/l. In samples directly taken at discharge structures, increased tritium concentrations of some 100 Bq/l to some 1,000 Bq/l are measured. As a result of mixing along the flow section, however, the tritium 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, strontium-90 and caesium-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 iodine-131, which is attributable to nuclear medicine applications. Transuranic elements are generally not detected.

In sediment and suspended matter samples, cobalt-60 is regularly detected and in some cases iodine-131, caesium-137, americium-241, cobalt-58 and manganese-54 with specific activities mostly below 50 Bq/kg dry matter (DM) are detected. However, particularly in lakes (e.g. Starnberger See, Schollener See, Schaalsee, Wittensee), three-digit values up to about 200 Bq/kg dry matter also occur for caesium-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 matter.

The increase in the content of fission and activation products in surface water caused by discharges of radioactive wastewater 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.

Integrated Measurement and Information System (IMIS) for monitoring environmental radioactivity

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 IMIS. Monitoring comprises all relevant environmental areas from the atmosphere and the surface waters up to sampling of foodstuffs and drinking water. The core piece is a network which, at present, comprises about 1,800 measurement stations for measuring the local gamma dose rate. The measuring network is based on local conditions and can be adapted. All data measured are continuously transmitted to the Federal Central Office (ZdB) for the surveillance of radioactivity operated by BfS and from there on to BMUKN.

The collected data is automatically and regularly exchanged via international platforms at European (EUropean Radiological Data Exchange Platform (EURDEP)) and global (International Radiation Monitoring Information System (IRMIS)) level. Via EURDEP, monitoring data from automatic monitoring systems are collected in 39 countries. The European data are then transferred from EURDEP to the IAEA-operated IRMIS. As a member state of the Council of the Baltic Sea States (CBSS), Germany also exchanges radiological data multilaterally between all CBSS member states in accordance with a binding protocol. In addition, there are bilateral plans/codes for the direct exchange of information and data between Germany and some neighbouring countries. In the bilateral exchange, measuring data are usually transmitted every ten minutes, while EURDEP routinely receives data on an hourly basis.

Via IMIS, 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 at any time, if 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 BMUKN, which essentially means that measurements and samples will be taken more frequently.

The data from IMIS are also used within the framework of international information exchange (→ Article 16 (2), page 145).

The IMIS measurement data is 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 2025.

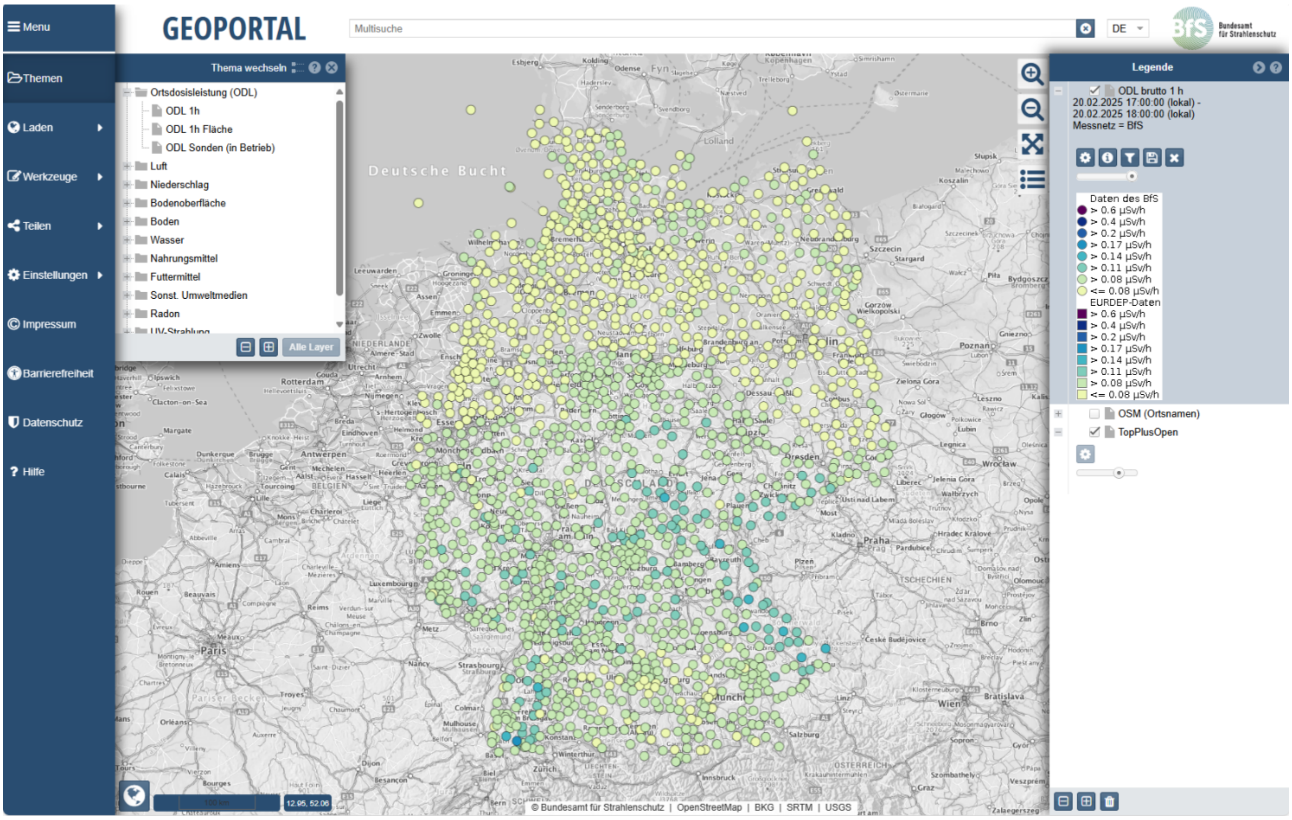


Figure 15-1 Example of the determination of environmental radioactivity by gamma dose rate measurements

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

Exposure of the personnel

In contrast to the previous National Reports, the following Figure 15-2 no longer differentiates the average type-specific annual collective doses of occupationally exposed persons of the nuclear installations in operation and in post-operation according to PWR generations and BWR construction lines. This is due to the fact that from 2019 and 2020 onwards, only one plant of BWR construction line 72 and one of PWR construction line 3 were in operation and an averaged presentation for these BWR and PWR construction lines therefore no longer appears meaningful from this year onwards.

Instead, Figure 15-2 shows the annual collective doses averaged over all German installations (BWR and PWR) in operation and post-operation, as well as the number of installations considered per year in each case.

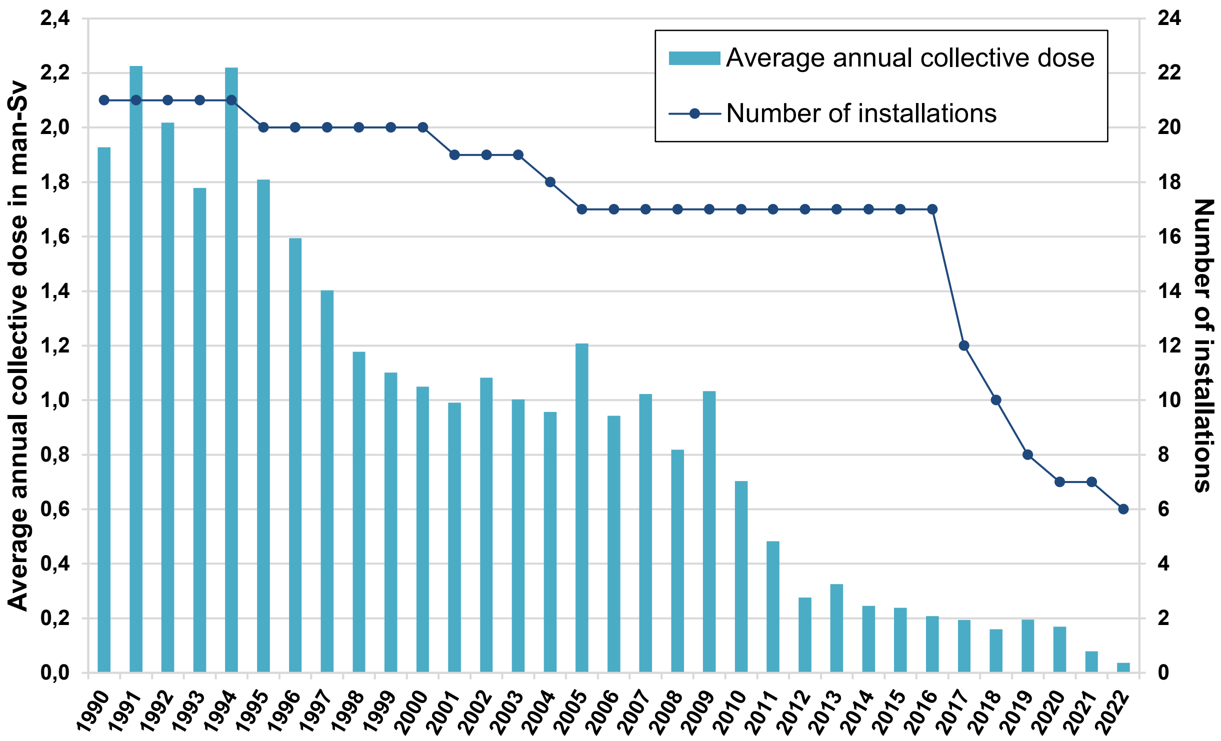


Figure 15-2 Average annual collective doses of occupationally exposed persons at nuclear installations in operation and in post-operation per year and installation

From 1995 onwards, a clear decrease in the average collective doses can be observed. This can be attributed to extensive backfitting and upgrading, especially in the older installations. For example, cobalt-containing material was replaced to varying extents and the scaffolding and handling of temporary shielding was optimised. These measures contributed to the long-term reduction of the collective doses in the older installations, while in the PWRs of construction lines 3 and 4 they led to fundamentally favourable radiological initial situations at an early stage.

In the period from 2001 to 2010, the values of the average annual collective dose fluctuated from year to year. This trend is largely determined by the rhythm of refuelling outages, especially of the older PWR installations (construction line 2).

In 2005 and 2009, the long-lasting and extensive overall maintenance and refuelling outages in two construction line 2 PWRs led to a corresponding increase in the collective doses. As a result of the shorter and reduced overall maintenance and refuelling outages of these plants in 2010, the values fell again. The further reduction in the collective doses observed in 2011 and 2012 is primarily related to the shutdowns of the older plants (BWRs of construction line 69 and construction line 2 PWRs) due to the 13th AtGÄndG of 6 August 2011 and the preceding moratorium of 15 March 2011. Since 2017, when five of the plants that had been in post-operation until then were no longer included in the graph due to the granting of decommissioning licences, the average installation-related annual collective doses have been at a consistently low level below 0.2 man-Sv.

The average dose per person in 2022 for installation personnel was approx. 0.09 mSv, while the average dose for contract personnel was approx. 0.07 mSv.

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 licensed limits. The data on discharges of radioactive substances with exhaust air and wastewater are published by the Federal Government in its annual report "Environmental Radioactivity and Radiation Exposure" submitted to the Bundestag, and in an additional more detailed annual report with the same name issued by BMUKN. Discharges from German nuclear installations are shown in Figures 15-3 and 15-4.

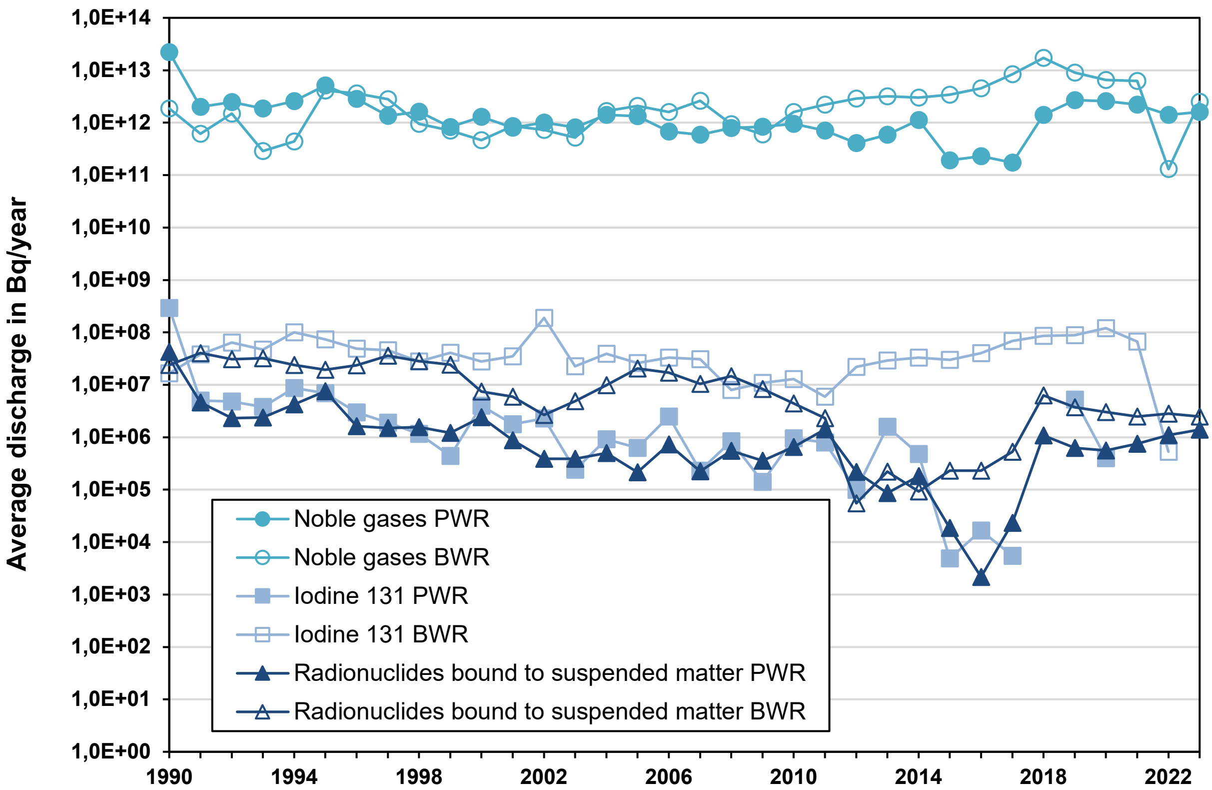


Figure 15-3 **Annual average discharge of radioactive substances with exhaust air from PWRs and BWRs in operation**

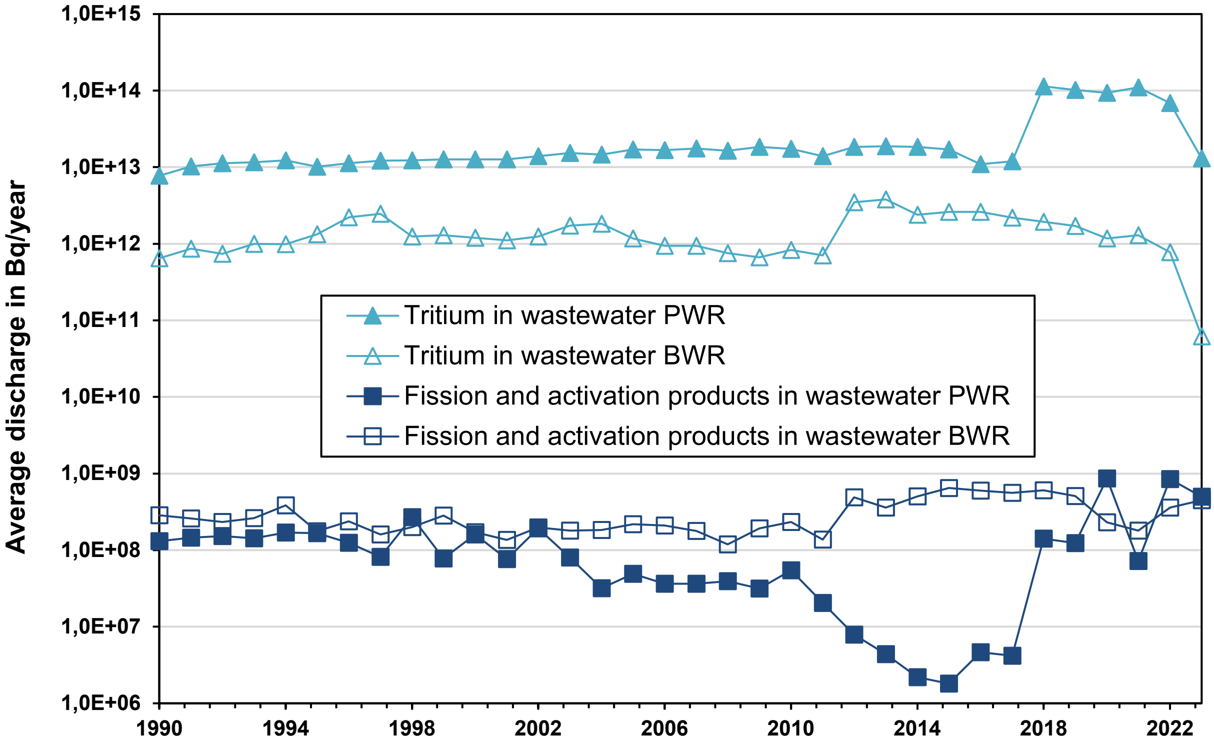


Figure 15-4 **Annual average discharge of radioactive substances with wastewater from PWRs and BWRs in operation**

Exposure of the public during specified normal operation

The results of the calculation of radiation exposure of the public show 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 FA defects (→ Figures 15-5, 15-6, page 125). The relevant limit of 0.3 mSv for the effective dose for a representative person is only reached to a very low fractional amount. For wastewater (→ Figure 15-7, page 126), the resulting exposures are even lower, with values generally less than 1 µSv. Up until and including the calendar year of 2019, these calculations were carried out according to the AVV on the determination of exposure from the discharge of radioactive substances from installations or facilities of 28 August 2012. Since the calendar year 2020, the calculations have been based on the requirements of the AVV “Determination of the exposure of members of the public through activities requiring a permit or notification” of 8 June 2020. Due to the new calculation basis, slightly higher dose levels for adults and infants now result in the area of wastewater, while in the area of exhaust air, the calculation of the thyroid dose for infants is no longer required.

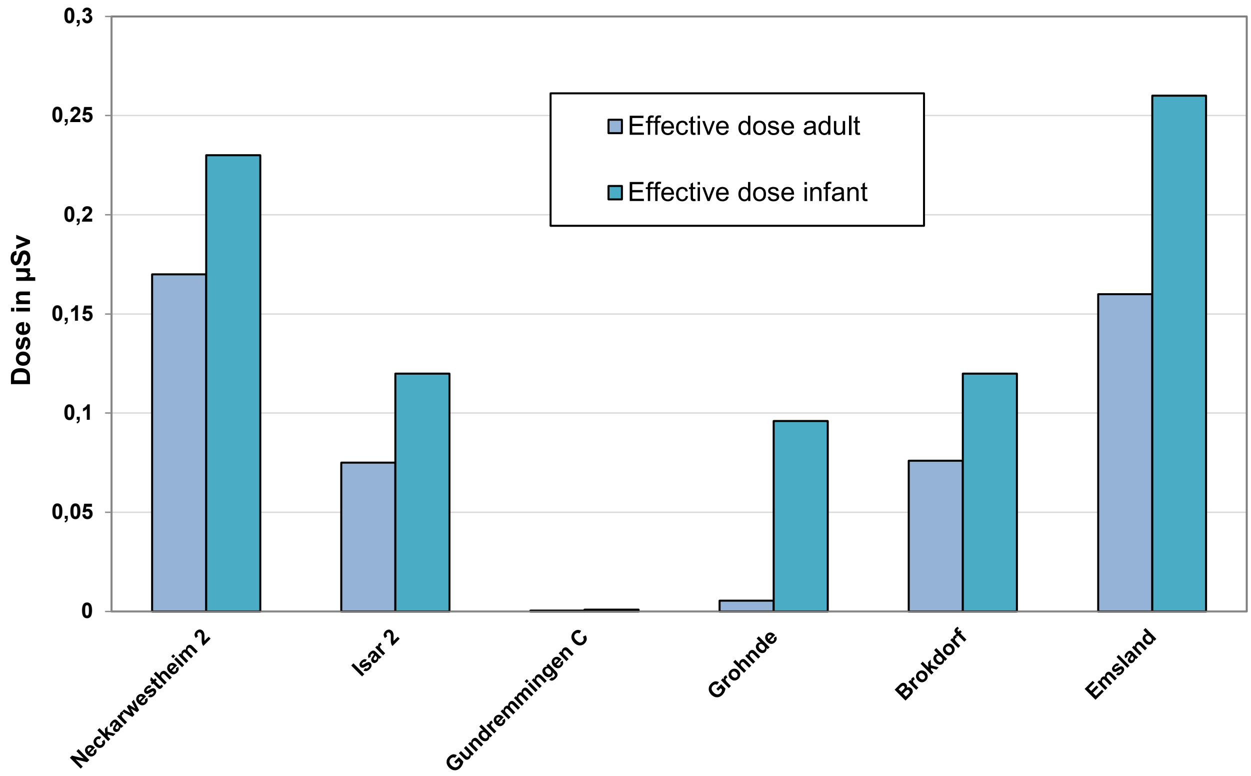


Figure 15-5 **Exposure in 2023 in the vicinity of the nuclear installations in operation due to discharges with exhaust air**

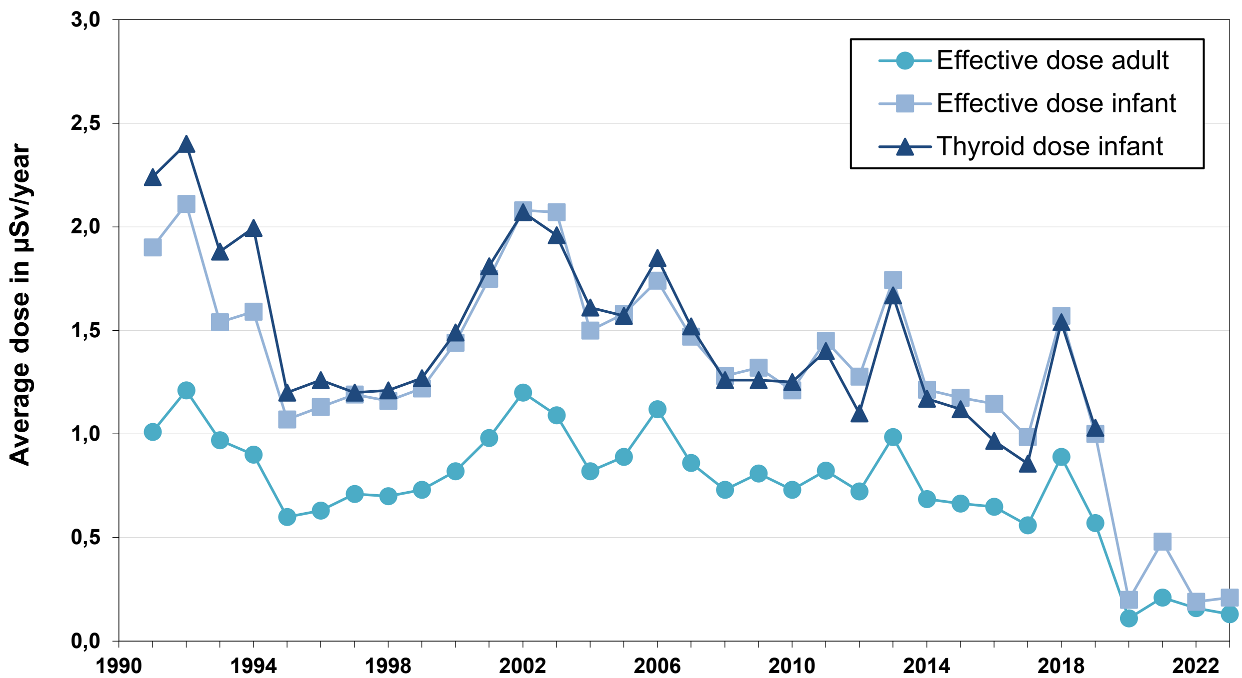
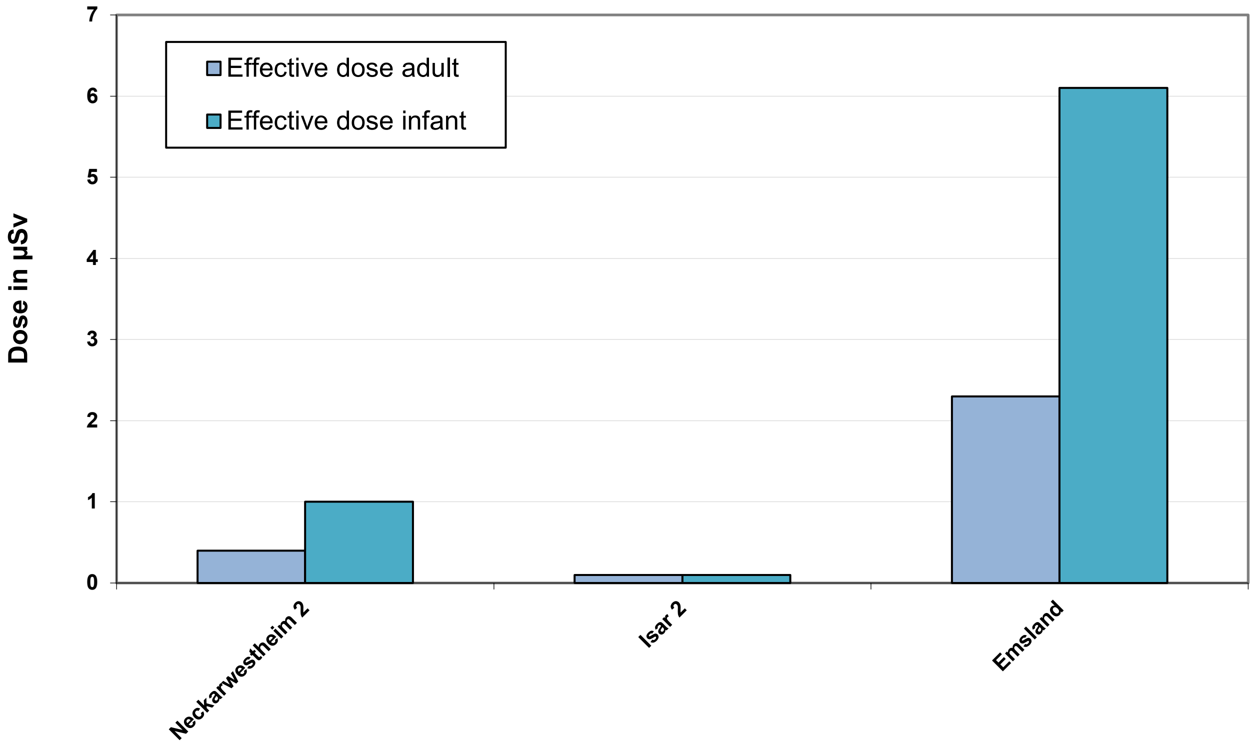


Figure 15-6 **Average exposure in the vicinity of the nuclear installations in operation due to discharges with exhaust air**



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

Figure 15-7 Exposure in 2023 in the vicinity of the nuclear installations in operation due to discharges with wastewater

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 competent licensing and supervisory authority. The licence holder supplements the proof of compliance with the dose limits by means of an additional measuring programme for the monitoring of the vicinity of the installation or facility.

The task of verifying the emission measurements carried out by the licence holder (self-monitoring) is assigned to BfS in § 103(4) StrlSchV. The control measurement programme for emissions of radioactive substances with exhaust air and wastewater is laid down in the Guideline on “Control of Self-Monitoring of Radioactive Emissions from Nuclear Power Plants”. For exhaust air, it comprises the determination of the activities or activity concentrations of radioactive substances bound to suspended matter, iodine isotopes, tritium and carbon-14 on different collection media such as HEPA filters, activated carbon and molecular sieves, as well as comparative measurements to determine the emission of radioactive noble gases. In the area of wastewater, samples are analysed for gamma-emitting nuclides, tritium, strontium-89/-90, iron-55, nickel-63, and alpha emitters. The results of the control measurements are submitted to the competent licensing and supervisory authorities. If the results of the measurements carried out by the licence holder correspond with those carried out by 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 competent 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 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 competent 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 competent licensing and supervisory authorities also monitor the emission and immission of radioactive substances with exhaust air and wastewater. For immission monitoring, the competent 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 their responsibility for emission monitoring, the licence holders regularly report to the competent 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 BfS are also taken into account. Any discrepancies will be examined within the scope of supervision. Where required, additional measurements (so-called 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 installations

In addition to the self-monitoring of the licence holder, the competent 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 competent licensing and supervisory authorities. 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 competent 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 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 StrlSchV on 31 December 2018. The Guideline on Emission and Immission Monitoring of Nuclear Installations (REI) has been revised, in particular to take into account experience gained from enforcement and to enable adaptation to the new radiation protection law. The revised guideline has been the basis for the enforcement of the Radiation Protection Act since 1 October 2023.

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 AtG, the 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 EU and Euratom (see Chapter 2 ANoPl-Bund).

Both in the area of on-site and off-site emergency preparedness, the legislative requirements (→ Article 7, page 33) 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, page 128).

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.

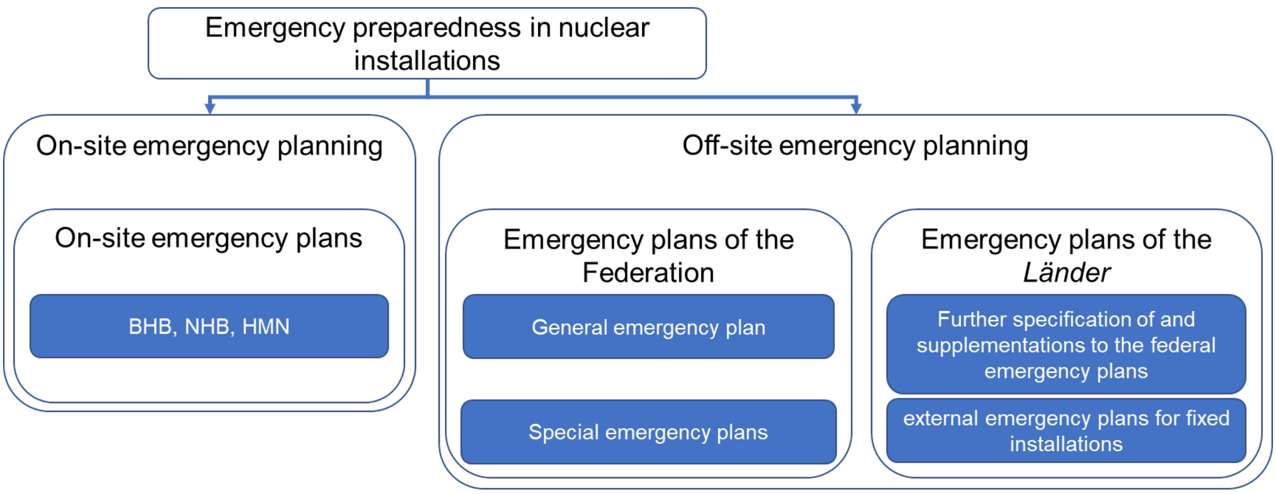


Figure 16-1 Structure of emergency preparedness for emergencies in connection with nuclear installations and facilities

Off-site emergency planning is part of the emergency management system, which comprises all legal, administrative, technical and organisational measures 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,

- 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
- 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 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 SiAnf and safety standard KTA 1203 “Requirements for the Emergency Manual” (→ Article 12, page 90).

Legal and regulatory requirements for external emergency plans

The StrlSchG contains a number of legislative requirements for the not-yet finalised preparation of new, coordinated emergency plans of the Federation (§§ 98, 99 StrlSchG) and the *Länder* (§ 100 StrlSchG) as well as for installation-specific external emergency plans for fixed installations and facilities with special hazard potential (§ 101 StrlSchG).). In the context of this report, the aforementioned plans relating to off-site emergency response are referred to as ‘off-site emergency plans’. This serves to distinguish them from the operators' “on-site emergency plans” (→ Figure 16-1, page 128).

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 the 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 NDWV with fixed dose levels for the measures “request to stay in buildings”, “request to take iodine tablets” and “evacuation” as well as the 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 according to § 98 (ANoPl-Bund) issued in 2023, 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. The reference scenarios are each provisionally allocated to one of the three emergency classes of supra-regional, regional or local emergency, based on their likely significant impact area. On this basis, the ANoPl-Bund provides basic protection strategies for supra-regional/regional and local emergencies, which shall in particular comprise the following:

- dose levels used as a radiological criterion for the adequacy of certain protective measures (unless already specified in the NDWV),
- 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,
- limit or guidance values for the existence of a threat from ionising radiation relating to specific, directly measurable consequences of the emergency, e.g. dose rates, contamination levels or activity concentrations, and
- criteria for the adjustment and cancellation of measures, to be used in particular in an open-ended review process for the maintenance, adjustment or cancellation of measures.

The ANoPl-Bund furthermore has to put requirements and instruments already provided in the StrlSchG 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 in concrete terms. This applies in particular to the definition of radiological criteria for a possible lifting of measures.

Pursuant to § 99 StrlSchG, the ANoPl-Bund is to be put in concrete terms by special emergency plans of the Federation (BNoPl-Bund) for specific administrative and economic sectors. The plans of the Federation are supplemented by each *Land* and put in concrete term by general and special emergency plans of the *Länder*. The BNoPl-Bund contains further differentiated protection strategies depending on the need and the expected impact on the respective administrative and economic areas.

Until the emergency plans of the Federation 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 emergency plans of the Federation. Until the emergency plans of the *Länder* are issued, certain documents and specifications shall be regarded as preliminary emergency plans of the *Länder* (§ 97(5) StrlSchG).

In local radiological emergencies, it is especially the fire brigade's emergency response teams that are activated. In its recommendation “The radiation accident - a guideline on initial procedures”, the SSK has issued guidelines for such events. The fire brigades and police units also have procedures on how to proceed in CBRN situations, which are set out in Fire Service Regulation 500 and Police Guide 450.

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

The StrlSchG also specifies the tasks and powers of the competent 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, the StrlSchG contains regulations on the following:

- measurement tasks of the Federation and the *Länder* for monitoring environmental radioactivity,
- operation of an IMIS under the responsibility of the ZdB at 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,

- on authorisations to regulate by ordinance the disposal of waste that is or may be radioactively contaminated as a result of an emergency,
- official information of the population in an emergency and recommendations on how to behave in the event of an emergency,
- content of a 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-Bund).

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 (also) 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.

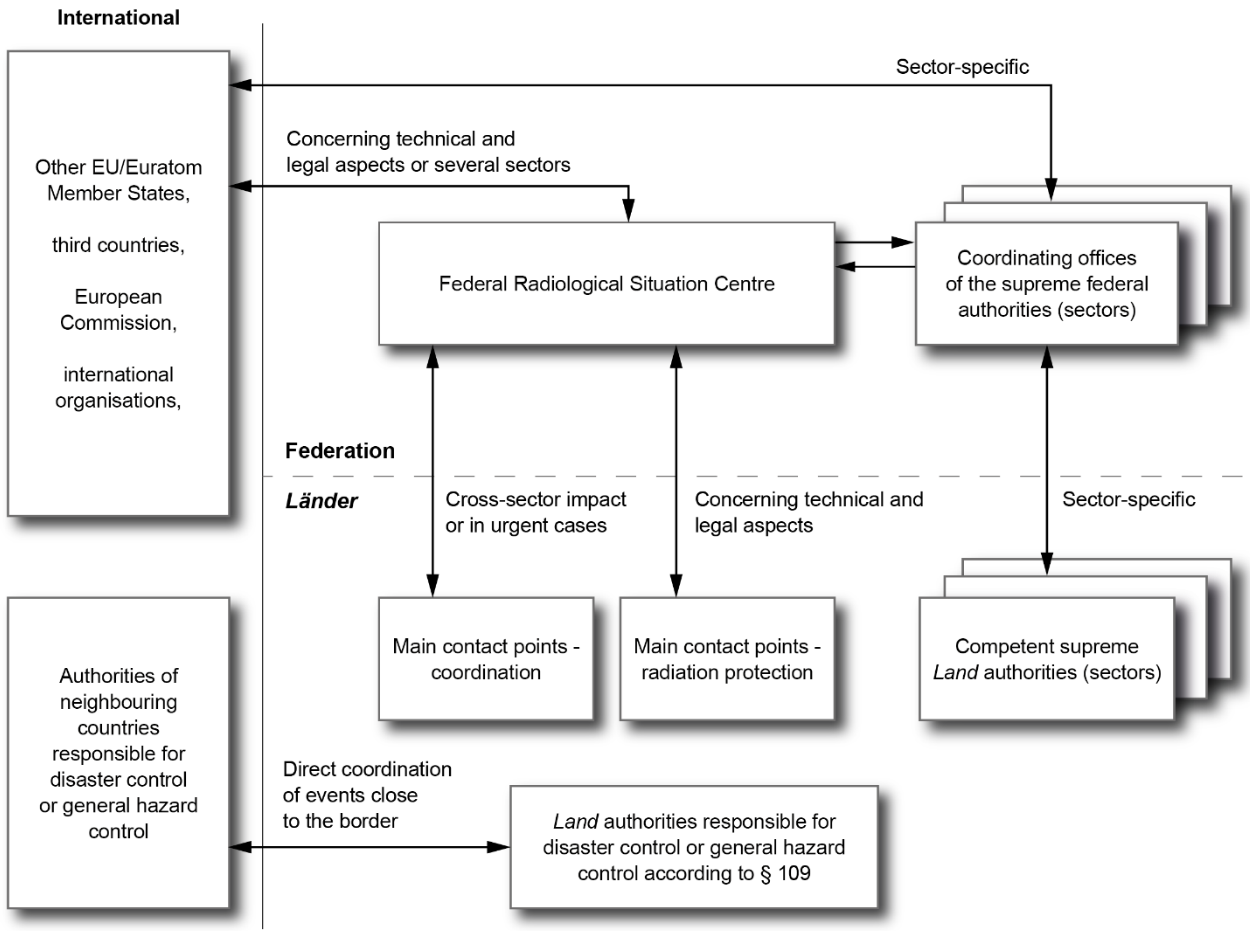


Figure 16-2 Emergency preparedness organisation

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 RSK and the SSK have jointly formulated general recommendations for the planning of emergency protection measures of the licence holder. These are part of the federal provisional emergency plans, which were last revised in 2014, and currently 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. They are 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 emergency management system of the Federation and the *Länder* also includes 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.

During an emergency, the *Land* authorities monitor the condition of the installation and compare the information received from the licence holder with the data from the KFÜ and, in the case of a radiological release, with the measured data recorded by IMIS outside the installation site. The supervisory authorities are authorised to carry out necessary examinations on the site of the installation and inside the installation.

In regional emergencies, the *Land* is usually responsible for drawing up the RLB unless this task has been handed over to the RLZ-Bund in advance by administrative agreement in accordance with § 108(2) StrlSchG, or the RLZ-Bund takes over this task in an emergency. Agreements are currently being prepared between BMUKN and the applicant *Länder* in which the modalities for technical support by the RLZ-Bund in the preparation of the RLB or the complete takeover of the RLB by the RLZ-Bund are defined. In the *Länder* with nuclear installations, the licensing and supervisory authorities operate the 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 supra-regional emergencies, which by definition include all emergencies at nuclear installations, the RLZ-Bund is always responsible for drawing up the RLB, which is binding for all authorities. The RLZ-Bund is a network consisting of BMUKN, BfS, GRS and further supporting federal authorities and is in close contact with the *Länder*, other federal ministries and competent authorities abroad, in particular with neighbouring countries as well as with the European Commission and the IAEA. The RLZ-Bund 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 administrative agreement with the RLZ-Bund to draw up the RLB also for regional emergencies, i.e. such emergencies that typically affect only one *Land*.

BMUKN is also responsible for the fulfilment of international information and reporting obligations, e.g. for the implement 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[36] as well as for the exchange of information in accordance with bilateral agreements for emergencies and fulfils these obligations with the RLZ-Bund. The RLZ-Bund is also responsible for coordinating requests for assistance within the framework of the Response and Assistance Network (RANET).

The Federation monitors and assesses the radiological situation with the ZdB at the BfS. For this purpose, it uses IMIS data 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 (→ Article 15, page 120). In an emergency, the ZdB is integrated in the RLZ-Bund.

The German Joint Reporting and Situation Centre (GMLZ) is the national contact point responsible for alerting the RLZ-Bund 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. For alerting by the licence holder, in addition to other stipulations, of particular relevance are the AtSMV, the external emergency plans for fixed installations or facilities with special hazard potential, the alert criteria (cf. Appendix 4 no. 2 StrlSchG) as well as the on-site emergency response plans. The licence holder or certain authorities are obliged to inform the competent supervisory authority, the local authority responsible for public safety, the disaster control authorities and the German Joint Information and Situation Centre (GMLZ) as a permanently available alert centre of the RLZ-Bund as well as the RLZ-Bund immediately if a reportable event fulfils certain specified alert criteria. These agencies 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 IAEA or other international organisations on the basis of the international or bilateral regulations and agreements concluded for this purpose,

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[36] Act on the Implementation of the International Health Regulations (IGV-DG), 21 March 2013, Federal Law Gazette I 2013 p. 566, www.gesetze-im-internet.de/igv-dg/IGV-DG.pdf

- when certain parameters of the automated plant-related environmental monitoring are exceeded, by the competent licensing and supervisory authorities, or
- when certain parameters of the IMIS monitoring are exceeded, by the ZdB for the monitoring of environmental radioactivity.

The ANoPI-Bund also provides alerting options for a variety of other situations. This includes, among other things, sector-specific reporting procedures such as the European Rapid Alert System for Food and Feed (RASFF), the European Rapid Alert System for Dangerous Non-food Products (Safety Gate) or the possibility of a self-alert of the RLZ-Bund or another authority or organisation in order to trigger the alert chain to the RLZ-Bund. In addition to the detection of increased measured values, self-alerting can also be triggered by messages in social media as well as television and radio reports and press releases or ad-hoc information transmitted by domestic or foreign authorities or organisations or by international organisations, including by non-formal means.

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 BHB and belongs to the safety specifications. The RSK and the SSK have jointly recommended criteria for the alert of emergency response authorities by the operators of nuclear plants, which are also part of the federal provisional emergency plans. 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 radionuclides 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 fulfilled, the licence holder will alert the disaster control authorities, indicating the corresponding stage of alert, the competent supervisory authority and the RLZ-Bund. Here, the technical criteria, e.g. very high temperature or low level in the 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), page 172). Specifications regarding the content and structure of the NHB are compiled in safety standard KTA 1203 “Requirements for the Emergency Manual” (→ Article 12, page 90). In their entirety, the regulations mentioned, especially the alarm regulations, the NHB, the HMN (→ Article 18 (i), page 157) 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 at short notice, and
- 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). 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.

General requirements for the emergency organisation are formulated in the recommendations “General guidelines for emergency planning by nuclear power plant operators” of the SSK and the RSK. Measures to establish the functioning of the emergency organisation are primarily aimed at the formation of a capable team that has all the necessary skills to assess the situation and to initiate corrective measures. In addition, resources are available for the implementation of measures such as means of transport, equipment, and an emergency centre.

Off-site emergency plans

As defined in § 101 StrlSchG, the competent disaster control authorities draw up installation-specific external emergency plans for fixed installations and 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). 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[37] that continue to apply as one of the federal provisional emergency plans. The external emergency plans focus on the interaction of the planning of the authorities and the measures provided by the authorities (especially the disaster control measures) and measures provided by the licence holder. The planning also includes the necessary measurements for determining the situation.

For emergencies linked to foreign nuclear installations that may make disaster control measures on German territory necessary due to their location close to the border, 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*.

The catalogue on assistance possibilities in the event of nuclear accidents published by BMUKN 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. In addition, BMUKN maintains a database on medical assistance options, which contains up-to-date data on hospitals that can provide assistance in the event of a nuclear accident and have the appropriate equipment for radiation accident patients.

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 wastewater.

Situation assessment

For accidents in nuclear installations and all other emergencies which may have not only local, but also regional or supra-regional effects, the StrlSchG provides for drawing up a uniform RLB. This is

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37 SSK recommendation “General Guidelines for emergency response in the vicinity of nuclear installations”, adopted at the 274th meeting of the SSK on 19/20 February 2015, https://www.ssk.de/SharedDocs/Beratungsergebnisse/DE/2015/Rahmenempfehlungen_Katastrophenschutz.html

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 assesses all relevant information available at the respective point in time on the radiological situation and its development to be further expected. 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 guidance 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 made available to all authorities and organisations with tasks and responsibilities in radiological emergencies. This also applies to the updates that are pre-pared at regular intervals. On the basis of the RLB and taking into account all other decision-relevant (i.e. non-radiological) circumstances of the emergency, the competent authorities decide on the appropriateness (and thus implementation) of the measures in question within their area of responsibility.

The assessment of the situation is performed with the available information about the plant state, the meteorological conditions 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[38] based on the lessons learned from the Fukushima nuclear accident within the framework of a recommendation. The recommendation "Source terms and early protective measures at nuclear power plant accidents where the situation is unclear" of 2019 is a supplement to this recommendation[39].

In the phase prior to the release of radionuclides into the environment, 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 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, page 127). RODOS can be used to calculate local, regional and supra-regional 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 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 has 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 is 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 (→ Figure 16-3, page 137)), the predicted situation is checked and adapted to the situation determined by measurements. The BfS and GRS have a database containing pre-calculated source terms for PWRs and BWRs that can be used if the licence holder is unable to provide a source term.

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38 SSK recommendation "Forecast and estimation of source terms in the event of nuclear power plant accidents", 270th meeting of the SSK, 17/18 July 2014, https://www.ssk.de/SharedDocs/Beratungsergebnisse_E/2014/Quellterm_e.html?nn=2876422

39 SSK recommendation "Source terms and early protective measures at nuclear power plant accidents where the situation is unclear", 300th meeting of the SSK, 27/28 June 2019, https://www.ssk.de/SharedDocs/Beratungsergebnisse_E/2019/2019-06-27Quellt.html?nn=2876278

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 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-Bund 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 be able 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.

BfS is currently developing a ‘Basic measurement strategy for supra-regional and regional emergencies including standards for the transmission of measuring data to the RLZ-Bund’ as a document to supplement the ANoPl-Bund. This is done because various other administrative and economic areas are affected in the event of an emergency. These can also provide for measurements and sampling can also be provided in their respective areas of responsibility as part of the emergency management system of the Federation and the *Länder*.

In order to have a comprehensible and standardised assessment basis for dose estimation in an emergency, in particular for the calculation methods to be used, assumptions and the exposure pathways to be taken into account, BfS is currently preparing the ‘Standards for the estimation of the emergency-related dose to the population’, also as a document supplementing the ANoPl-Bund.

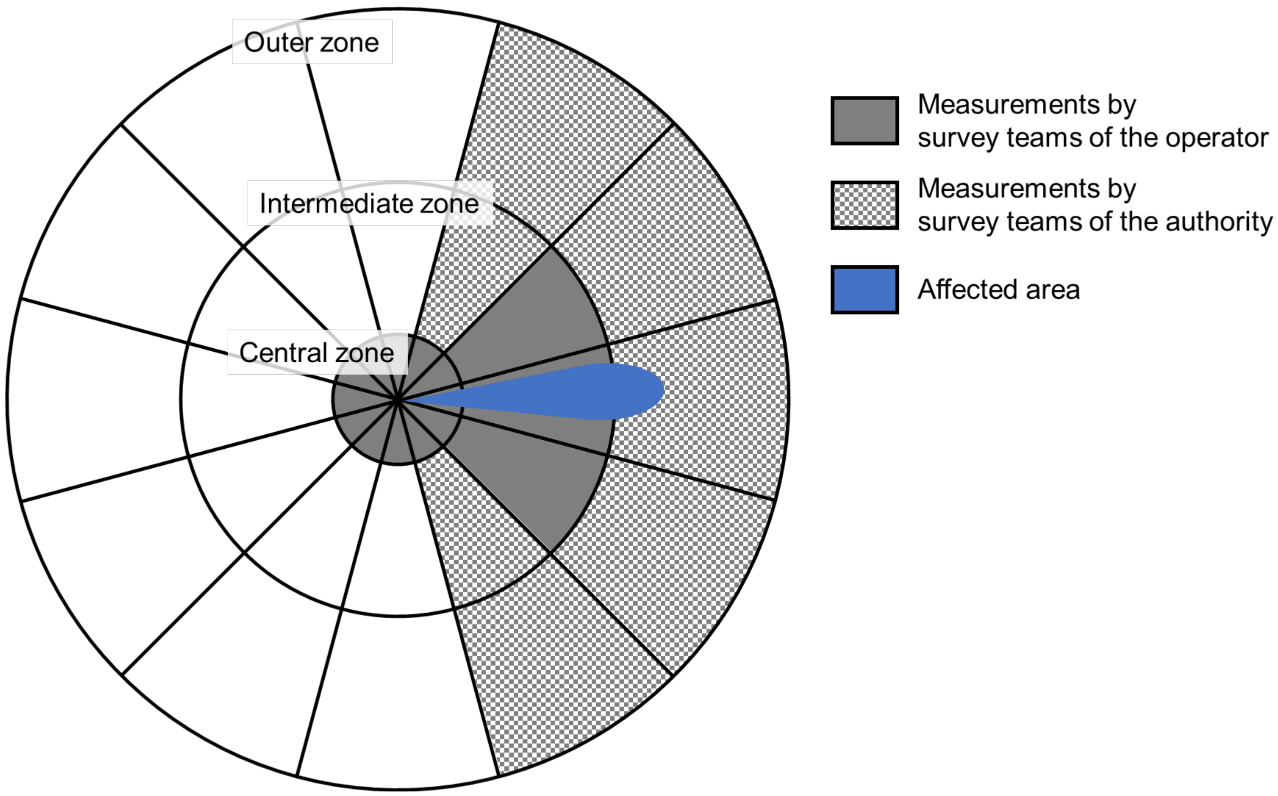

Figure 16-3 Deployment areas of the different measuring and sampling teams

Off-site measures

Criteria for emergency management measures

The constitutional duty to protect life and physical integrity gives rise to the following radiological protection objectives in accordance with Article 97(3) of Directive 2013/59/Euratom, which must be taken into account in emergency planning and response:

1. Severe deterministic effects shall be avoided as far as possible. To this end, the emergency-related radiation dose to the public and emergency workers shall be limited by appropriate measures to levels below the threshold doses of such effects as far as possible. (→ Table 15-1, page 114).
2. The risk of the occurrence of stochastic effects on the population and the emergency workers shall be kept as low as possible by taking appropriate measures to reduce the emergency-related effective dose.

In this context, all persons who perform a defined task in an emergency or other hazardous situation and who may be exposed during their deployment are considered to be emergency workers.

The term “emergency worker” in radiation protection law is to be interpreted broadly. It includes, for example, installation personnel, public safety and rescue personnel (e.g. police, plant and public fire brigades or rescue services), but also support personnel involved in protective measures.

In order to ensure compliance with the radiological protection objectives as far as possible and to enable the authorities and organisations involved in emergency response to make timely decisions on the implementation of appropriate protective measures in the event of an emergency, various radiological criteria are defined in the form of dose levels and limit or guide values as part of the optimised protection strategies of the ANoPl-Bund.

Recommendations from publications 103 and 109 of the ICRP, the IAEA’s Basic Safety Standards[40], Directive 2013/59/Euratom and lessons learned from the Fukushima nuclear accident were taken into account in these specifications. For a rapid implementation of 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[41] 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 emergency management.

The ANoPl-Bund defines radiological criteria below which the lifting of previously taken protective measures of emergency management must be considered. For most measures, the criteria are identical to the criteria for taking measures. According to §§ 109 and 111 StrlSchG, when considering the lifting of protective measures, 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 are to be taken into account. According to § 118 StrlSchG, one prerequisite for a transition of an emergency exposure situation to an existing exposure situation is a safe level below the effective dose of 20 mSv per year for the affected population.

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

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

[41] “Artikel 2 – Verordnung zur Festlegung von Dosiswerten für frühe Notfallschutzmaßnahmen (Notfall-Dosiswerte-Verordnung – NDWV)“; proclaimed as Art. 2 of „Verordnung zur weiteren Modernisierung des Strahlenschutzrechts“, 29 November 2018 (BGBl. I S. 2034); Entry into force according to Art. 20 Abs. 1 p. 1 of this regulation on 31 December 2018

Table 16-1 Dose levels for early protective measures

Measures	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		Committed equivalent dose (thyroid) from radio-iodine inhaled within seven days, assuming staying outdoors without taking protective factors into account
	250 mSv individuals aged 18 to 45		
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

Early protective measures

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 early protective measures of disaster control are provided:

- sheltering,
- taking potassium iodide tablets (iodine tablets), also referred to as iodine thyroid blocking, and
- evacuation.

The dose levels specified in the NDWV (→ Table 16-1, page 138) have to be used as radiological criteria for the adequacy of the three protective measures mentioned therein. Depending on the situation, the early protective measures are supplemented by various accompanying measures as well as behavioural recommendations (especially recommendations regarding the consumption of food).

Planning areas for the above measures have so far been based on an SSK recommendation that takes risk analyses carried out by BfS into account and is part of the federal provisional emergency plans. 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 have been shut down permanently, the planning radii of power operation shall be maintained for 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, reduced radii shall 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. Furthermore, the planning areas for different installations and the associated requirements are defined in the BNoPl-Bund.

Table 16-2 Planning radii for early protective measures in the vicinity of nuclear installations

Nuclear installation	Zone	Radius	Pre-planned measures
Nuclear installations in power operation Nuclear installations shut down permanently with irradiated fuel in the first 3 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
		Within the entire federal territory	• Iodine thyroid blocking for children, teenagers and pregnant women
Nuclear installations shut down permanently with irradiated fuel 3 years after the date of the final shutdown	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	up to 2 km	• Sheltering • Iodine thyroid blocking • Evacuation within 24 h
	Intermediate zone	up to 8 km	• Sheltering • Iodine thyroid blocking
	Outer zone	up to 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, extensive information is available for the population in connection with the iodine thyroid blocking, which can be found on the website www.jodblockade.de. The iodine tablets are usually only pre-distributed in the central zone, while in the other zones they are distributed at collection centres in the event of an emergency. However, the exact implementation is the responsibility of the local disaster control authority. The latter must ensure that the distribution of iodine tablets is completed within six hours in the central zone and within twelve hours in the intermediate zone.

Table C.2.5 of the ANoPl-Bund provides short-term initiation of reflex responses in order to protect the population (warning the population, sheltering, taking of iodine tablets) in the event of rapidly evolving events with imminent core meltdown. These measures can then be taken without the need for forecast calculations.

In addition to these measures, further measures are taken for the predicted area to reduce the dose contribution via the foodstuffs pathway and warnings are issued against the consumption of freshly harvested contaminated foodstuffs. If no forecasts are possible, this is done up to the distances specified in Table C.2.12 of the ANoPl-Bund. Once reliable forecasts or corresponding measurement data are available, these measures will be adapted to the situation. Beyond that, the following further measures must be included in 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, and
- banning the circulation of contaminated foodstuffs and feedstuffs.

Protective measures and other measures in later phases of an emergency

Emergency management measures in later phases of an emergency serve to reduce the exposure of the population also in areas where the early 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 wastewater.

Technical information on emergency measures

A catalogue of measures is currently available as a provisional emergency plan in accordance with Annex 4 No. 5 StrlSchG as a technical aid for the competent authorities responsible for ordering the measures. This is currently being updated and will then be published as a document supplementing the ANoPI-Bund. This ‘loose-leaf collection’ consists of numerous sheets of measures, each of which deals with a specific protective measure from an interdisciplinary perspective (i.e. from the point of view of radiation protection and other areas affected by the measure). The sheets of measures contain i.a. technical and organisational information to support the competent authorities in deciding on protective measures as well as in preparing and implementing them.

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 backfitted at existing nuclear installations. These 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.

Due to the federal structure in Germany, the coordination of emergency measures between the various actors at federal and *Länder* level is very complex. This is particularly true for foreign nuclear installations close to the border, where a rapid exchange and coordination of information on the state of the installation and the coordination of protective measures across state borders is required. This affects the responsibilities of various federal and *Land* authorities. The interaction between the RLZ-Bund and the other actors of the German emergency management system as well as the international counterparts is also being continuously optimised by the authorities involved.

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[42].

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, external impact events, events with 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 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. In this context, transport to and from the site as well as radiation protection in case of an emergency are taken over by KHG. The staff at the site are deployed to perform their "usual" tasks in accordance with the NHB with radiation protection gear.

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

[42] Recommendation of the SSK and the RSK "General guidelines for emergency planning by nuclear power plant operators", last adopted at the 468th meeting of the RSK (4 September 2014) and at the 271st meeting of the SSK (21 October 2014), https://www.ssk.de/SharedDocs/Beratungsergebnisse/DE/2014/Notfallmassnahmen_Betreiber_Kernkraftwerke.html

competent 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 competent 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 during the current review period from 2022 until 2025 with regard to

- 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, 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:
    - determination and assessment of the situation,
    - coordination of the decisions of the competent authorities and
    - 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. So far, the potentially affected population has not been actively involved in these exercises. In some exercises, the distribution of iodine tablets was practised to the point where they would then have been handed out to the population. It is planned to involve the population in future exercises for practising crisis communication.

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 mostly on a scenario with postulated release of radionuclides 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. One such example is the LÜKEX exercise, which was carried out in 2023 and assumed a cyberattack on government action and in which the aim for the exercisers was to maintain state and government functions, among other things by prioritising business processes. In 2024, the RLZ-Bund took part in a national emergency response exercise in the form of a partial exercise together with the staffs of the participating *Länder*. The exercise assumed a reactor accident involving a civilian icebreaker in the Baltic Sea and aimed to test the communication and coordination procedures between the national administrative structures, in particular with the German Central Command for Maritime Emergencies.

Regular measuring and sampling exercises are another component of the exercise programme in order to ensure the operational readiness of the measuring teams and any other parties involved, such as laboratories, and to optimise processes. In 2023, a fictitious release of radionuclides from a foreign nuclear installation near the border was assumed, which led to the IMIS being moved into intensive operation mode and thus made it necessary for the measuring centres of the *Länder* and the federal authorities to carry out sampling and measurements in a large number of different environmental media.

In 2024, an unannounced exercise was carried out to check the operational readiness and the capacities actually available to fulfil the intensive IMIS operation. However, unlike in the 2023 exercise, no real samples were taken.

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.

At the beginning of 2024, the RLZ-Bund took part in a trilateral communication exercise with France and Luxembourg. This was based on an incident assumed by France to have occurred at a French nuclear installation.

On principle, the regular exercises of the EU (ECURIE[43] exercises), the IAEA (CONVEX) and the OECD/NEA (INEX) are attended by RLZ-Bund staff according to their responsibilities. In addition, depending on the exercise situation, supporting bodies, other federal ministries and the competent licensing and supervisory authorities of the *Länder* are also involved. In 2024, the RLZ-Bund took part in four modules of the INEX 6 exercise together with specialist authorities from various fields. The exercise was designed as a simulation game and focussed in particular on the phases following a release. Germany prepares to participate in a CONVEX 3 exercise in 2025.

In order to further develop and harmonise nuclear emergency preparedness internationally at a sufficiently high level, staff of BMUKN and experts working on behalf of BMUKN participate for Germany in the relevant bodies of e.g. 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 competent licensing and supervisory authorities.

External reviews

Like the other emergency plans of the Federation and the *Länder*, the external emergency plans for fixed installations and 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 information of the population in connection with radiological emergencies is regulated in the StrlSchG, in the StrlSchV as well as in the ANoPl-Bund. This concerns both the responsibilities of the authorities and the obligations of the licence holders as well as what has to be communicated. Further specifications are laid down in a crisis communication plan supplementing the ANoPl-Bund as well as in the other emergency plans of the Federation and the *Länder*. Basically, a distinction is made between information about possible emergencies in the context of emergency preparedness and information in the event of an actual emergency.

Informing the population as an emergency preparedness measure

In accordance with the statutory regulations, the competent agencies of the Federation and the *Länder* publish the respective emergency plans.

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[43] European Community Urgent Radiological Information Exchange

According to § 105 StrlSchG and § 106 StrlSchV, further information shall be made available to the population that may be affected by emergencies. This includes, among other things

- 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 competent licensing and supervisory authorities is the information portal of the Federation and the *Länder* (→ Article 8 (ii), page 71),edited by BMUKN that 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 in an emergency

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 § 112 StrlSchG in conjunction with Annex 7 StrlSchG and the ANoPl-Bund and give recommendations for behaviour. If the emergency leads or could lead to a disaster, the disaster control authorities and the RLZ-Bund have parallel competences. The delimitation of these competences and the necessary coordination are regulated in the ANoPl-Bund and are further specified in the crisis communication plan. 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 alerting 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 their area of responsibility at the same time. These systems include, for example, radio, television, digital information boards as can be found in urban areas, sirens and dynamic passenger information systems. With the new ‘Cell Broadcast’ technology introduced in Germany on 23 February 2023, warnings are sent directly to modern mobile phones and smartphones via wireless communication. The federal emergency information and message app (NINA) is connected to MoWaS and is one of several warning apps that are supplied. NINA can be used e.g. to issue quickly and effectively warning messages and emergency tips on smartphones. The RLZ-Bund 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 designed for civil protection. Currently, there are about 108 authorised MoWaS stations connected to the secured core network in the Federal Republic of 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):

- call 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 for emergency response in the vicinity of nuclear installations"[44]. 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-Bund 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 Euratom to the extent necessary to prepare a coordinated emergency response. Germany has agreed bilateral plans/codes with some neighbouring countries, such as the Netherlands and Switzerland, for the direct bilateral exchange of data and information. These documents regulate organisational and technical details of data exchange to varying degrees of detail. As a rule, BfS is responsible for the international exchange of data. However, especially in the case of nuclear installations in border areas, the cross-border exchange of data can also take place at *Länder* level. Bilateral working groups routinely review the common rules for data and information exchange and evaluate and update their implementation at annual meetings. These meetings are usually attended by personnel from federal, *Land* and local authorities.

In Germany, the RLZ-Bund 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 particular law.

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44 SSK recommendation "General Guidelines for emergency response in the vicinity of nuclear installations", 274th meeting of the SSK, 19/20 February 2015, https://www.ssk.de/SharedDocs/Beratungsergebnisse/DE/2015/Rahmenempfehlungen_Katastrophenschutz.html

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 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 2022

During the review period, the ANoPl-Bund was issued as a general administrative regulation in the area of emergency preparedness in November 2023.

This is an important addition to the legal and administrative framework for emergency preparedness and response and is intended to ensure timely, effective and coordinated action by all authorities and organisations involved in the emergency response as well as a uniform assessment of the radiological situation on the basis of previously agreed, optimised protection strategies.

In 2023, an IRRS follow-up mission took place. In connection with emergency preparedness and response, there were two suggestions from the IRRS mission that were successfully finalised as part of the follow-up mission[45].

BMUKN asked the SSK to deliberate on various issues relevant to emergency preparedness and response. The SSK published three recommendation documents in the review period. In 2023, recommendations were issued on minimum requirements for hospitals with regard to structural, personnel and equipment capacities and on content for a curriculum as well as a proposal for implementing these recommendations in the emergency management system of the Federation and the *Länder* with the document ‘Medical management of radiation emergencies - Requirements and organisational matters’. Based on the lessons learnt from the reactor accident in Fukushima and the current WHO guideline on iodine thyroid blocking, the SSK published an update of the publication ‘Verwendung von Jodtabletten zur Jodblockade der Schilddrüse bei einem kerntechnischen Unfall’ in 2024 at the request of BMUKN. As a result of a change in the assessment of the security situation in Germany, the SSK was commissioned by BMUKN in March 2022 to assess the extent to which the various protective measures planned for radiological emergencies could also be effective in principle and appropriate from a radiological point of view in the event of a nuclear strike and which special requirements would have to be observed when implementing these measures. The recommendation was published in the last quarter of 2024 and aims to adequately improve current preparedness in Germany.

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[45] ”Report of the IRRS Follow-up Mission to Germany”, October 2023, https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/irrs_follow-up_mission_final_report_bf.pdf

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.

As already described in the introduction, some of the information presented is no longer relevant due to the discontinued use of nuclear energy for the commercial generation of electricity in Germany (power operation of nuclear installations).

17 (i) Site evaluation

Since § 7(1) 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 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 served 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”, which was revised at the end of 2022. 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. An additional assessment of the robustness of the nuclear power plants against flooding was performed by the RSK after the reactor accident in Fukushima. The basis for this assessment was the assumption of a flood with a probability that is one order of magnitude lower than the design basis flood (i.e. a flood with an occurrence frequency of 10^{-5}/a). The assessment concluded that sufficient safety margins are available also for a flood event with this low probability. The assessment was re-evaluated by the operators with regard to the investigations and follow-up investigations on which the design was based within the framework of the post-Fukushima National Action Plan, which showed no need for additional measures.

Against the background of international developments, e.g. Issue T of WENRAs Guidance on SRLs, the RSK discussed different aspects in connection with the determination of the design basis flood and examined to what extent specifications in relation to the relevant current requirements in the German rules and regulations are to be recommended. The most important aspects identified were a systematic assessment of uncertainties within the framework of the flood hazard analysis and a comparison of the determined design flood with historical events.

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 RSK[46] 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.

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[46] RSK statement “Aspects of the determination of the site-specific design basis flood”, 481st meeting of the RSK,10 February 2016; https://www.rskonline.de/sites/default/files/reports/epanlagersk481hpen_0.pdf

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 safety standard 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 safety standard 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 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 MSK scale). The RSK Committee on Plant and System Engineering (AST) discussed three re-assessments for impacts at German nuclear power plant sites and came to the conclusion that the requirements of safety standard KTA 2201.1 form an adequate basis for the assessment of earthquakes according to the state of the art.

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 re-assessment purposes.

Where re-assessments of nuclear power plants that have ceased power operation show that the seismic hazard has increased, the authority can initiate supervisory measures and impose conditions (e.g. removal of the radioactive material stored there or backfitting such as reinforced supports for pipes). Here, the appropriateness of the measure is taken into account.

Within the framework of the safety review (SÜ) of the nuclear installations to be carried out every ten years, the impact of the site on the safety of the nuclear installations is also re-assessed. Moreover, 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, among other things, that for all sites, there are safety margins to the design requirements regarding the seismic risk due to the conservative design and the seismic activity at the sites

Thus, the radioactive material is adequately protected against earthquakes also in a nuclear installation that is no longer in operation.

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 SiAnf 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), page 170) 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 SiAnf 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.

In 2021, the RSK published the “Summary statement of the RSK on man-made hazards, aircraft crash”.[47]

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 so 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

[47] RSK statement “Summary statement of the RSK on man-made hazards, aircraft crash”, 524th meeting of the RSK, 21 October 2021, https://www.rskonline.de/sites/default/files/reports/RSK-EP-Anlage1_RSK524_Stgn_FLAB_hpen.pdf

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), page 44). 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 the 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 BHB or it must possibly be shut down.

The last nuclear installations that have been in operation in Germany are located at river sites. The permissible heat emissions are regulated in the plant- and site-specific licences. The basis for this includes Directive 2000/60/EC (Water Framework Directive) and the Federal Water Act (WHG). From a technical point of view, the hydrological parameters of the respective river, such as discharge, flow velocity, existing water temperature, seasonal changes, etc., play a significant role in determining the permissible limit temperatures and heating margins, which generally lead to a specific heat emission via cooling towers. For an approximate specification of the temperature range, exemplary values, which may vary for different installations, are given as follows:

- The calculated mixing temperature of the river water after discharge and complete mixing of the cooling water must not exceed 28°C.
- The cooling water temperature at the point of discharge (before mixing) must not exceed 35°C.

- The cooling water discharged into the river must not be more than 10 K warmer than the water withdrawn from the river during once-through cooling and discharge cooling.
- The calculated heating margin in the river due to the cooling water introduced must not exceed 1 K.

A separate licensing procedure under water law is required for the utilisation of water and the discharge of cooling water and wastewater, 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 competent licensing and supervisory authority 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, page 33) is regulated in the AtVfV. According to § 15(2) sentence 1 AtVfV, the competent 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 competent 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 competent licensing and supervisory authority will carry out this review and will take it into account in its decision. In this context, § 14a AtVfV is of special importance.

§ 14a(1) AtVfV obligates the competent 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 competent 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 competent 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), page 103) 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 SiAnf 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 SiAnf 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" (→ Annex 3, page 195. In this respect, the following hazards have to be considered in particular:

- natural external hazards 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, as far as to be considered site-specifically, 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 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 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, the European Commission is informed of any plan for the discharge of radioactive waste in whatever forms in accordance with Article 37 of the Euratom Treaty for assessing possible impacts of projects on neighbouring countries. 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

Germany regularly exchanges information with its neighbouring countries on issues relating to 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.

Annual meetings are held with these countries for consultations between the nuclear regulatory authorities on issues of nuclear safety and radiation protection. The intergovernmental exchange of information includes, in particular, reporting on

- developments in nuclear energy policy and radiation protection,
- developments in nuclear and radiation protection law and substatutory regulations,
- technical or licensing-relevant modifications to nuclear installations, and
- operating experience, especially with regard to reportable events.

BMUKN, the competent authorities of the *Länder* bordering the respective neighbouring country and, if necessary, other participants are represented at the annual bilateral meetings on the German side.

The exchange of information within the framework of bilateral cooperation enables the neighbouring countries to better assess the potential impacts of nuclear installations in border regions 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 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), page 155). 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, among others,

- 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}/a, 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 competent 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.

As already described in the introduction, some of the information presented is no longer relevant due to the discontinued use of nuclear energy for the commercial generation of electricity in Germany (power operation of nuclear installations).

18 (i) Implementation of the defence-in-depth concept

Overview

According to § 7(2) 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. Section 2 (1)) of the SiAnf requires the following: “In order to meet the radiological safety objectives, the radioactive materials present in the nuclear power plant shall be multiply 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.”

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 fundamental 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 ISIs,

- 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).
  The main objective of the 30-minute criterion is to give the control room personnel sufficient time to identify the accident sequence, to check the fulfilment of the three fundamental safety functions and to decide, based on the procedures described in the BHB and NHB, which measures must be initiated to control the design basis accident and to avoid escalation to more severe accident conditions (→ Article 19(iii), page 168). For a few design basis events (e.g. steam generator tube ruptures), manual procedures are described in the BHB to follow an optimised strategy for dealing with the specific event.

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. due to 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. This 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 FA 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 SiAnf 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. If this is not possible, the radiological consequences should be limited 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.

According to the SiAnf, the occurrence of an event, an event sequence or a state can be considered as excluded if it is physically impossible to occur or if it can be considered with a high degree of confidence to be extremely unlikely to arise. There are no explicit quantitative exclusion criteria in the German legal ordinances. The RSK statement on its understanding of safety philosophy[48] provides guidelines for the grouping of events.

Section 4.4 "Accidents involving severe fuel assembly damages" of the SiAnf 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 HMN as a supplement to the existing NHB. The strategies and procedures contained in these manuals correspond to the international recommendations on SAMGs.

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[48] RSK statement "RSK's understanding of safety philosophy", 460th meeting of the RSK, 29 August 2013; https://www.rskonline.de/sites/default/files/reports/epanlagersk460hp05122013en.pdf

Improvements in systems engineering carried out on the basis of deterministic and probabilistic assessments since 2022

The continuous improvement of nuclear safety has always been an important feature of the German regulatory environment. Since the beginning of the use of nuclear energy in Germany, safety upgrades have been continuously carried out at German nuclear installations. These backfits were technically based on findings from lessons learned, operating experience, safety analyses and findings from research and development. The national nuclear regulations in Germany are constantly being further developed and continuously adapted to the progressing state of the art in science and technology. BMUKN keeps itself continuously informed about developments in the field of nuclear safety. Whenever new safety-related findings are available from ongoing supervision (§ 19 AtG), their transferability to other nuclear installations and the necessity of possible backfitting measures are examined. Numerous safety improvements have been implemented in German nuclear installations as a result of the processes anchored in the German regulatory framework. In particular, safety improvements were identified on the basis of an extensive analysis of the operating experience of nuclear installations in Germany and abroad. The modifications and improvements since 2022 resulted mainly from the operational experience feedback due to GRS WLNs. 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.

In summary, it can be said that Germany has had very good experience with the approach of continuous improvement of its nuclear installations, both through continuous and supplementary periodic SÜs. These approaches ensured in the review period that the German nuclear installations achieved a high level of safety which corresponded to the necessary precautions according to the state of the art in science and technology to prevent damage.

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 levels 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, page 33) 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 lowest category can be carried out by the licence holders on their own responsibility. Modifications of the next higher category require the approval of the nuclear supervisory authority, while modifications of the highest category require a licence by the competent licensing authority of the individual *Land.* 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 (→ Article 14, page 100 and Article 19, page 178) and the root cause analysis including MTO interaction (→ Article 12, page 87 and Article 19, page 178) also with regard to further optimisation possibilities. Additional regulatory control takes place within the framework of the SÜ (→ Article 14, page 103).

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 SiAnf 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 KTA contain further extensive requirements regarding qualification and proof of incorporated technologies and the reliability of safety-relevant SSCs. 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 following 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 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. reactor coolant pressure 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 competent 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 reactor coolant pressure 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 are submitted to the competent licensing and supervisory authority for review.

Analyses, tests and experimental methods for the qualification of technique applied and new technologies

Suitability and qualification of the technologies applied is proven in various ways by

- 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, page 178).

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 their 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 licensing and supervisory authority. Decisions are taken by the competent licensing and supervisory authority.

18 (iii) Design for reliable, stable and easily manageable plant operation

Overview of the regulatory basis

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 SiAnf.

High reliability of systems and components has already been achieved during design, construction and manufacturing by adherence to the design principles. These included 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 ensured a reliable and undisturbed operation and reduces the probability of occurrence of incidents and accidents.

Section 3 “Technical requirements” of the SiAnf includes requirements for the ergonomic design of the prerequisites for reliable personnel actions. Detailed requirements are defined, among others, in the safety standards of the KTA. 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, page 72).

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 safety standards of the KTA. The basic safety of a plant component is determined 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, page 195). 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 ISIs, indication changes or service-induced cracks must not occur. 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 current review period from 2022 to 2025.

Monitoring and control by the competent licensing and supervisory authorities

Prior to implementation, the licence holder of a nuclear installation has to submit modifications relevant to safety of the installation or its operation to the licensing and supervisory authority for licensing or approval within the supervisory procedure (→ Article 18 (i), page 157). 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" is not relevant 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.

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.

As already described in the introduction, some of the information presented is no longer relevant due to the discontinued use of nuclear energy for the commercial generation of electricity in Germany (power operation of nuclear installations).

19 (i) Initial authorisation

In Germany, the granting of a licence is regulated in § 7 AtG and in the AtVfV. The licences for construction and operation of the last three 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 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:

- <u>Commissioning of the systems</u>
  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.
- <u>Hot functional run, Phase 1</u>
  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 competent 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 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, 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 and presenting 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), page 173).

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 competent 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), page 86), 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 licensing and supervisory authority. Should the competent 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 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, page 72).The approved procedures for operation, including maintenance and testing, but also for the management of anticipated operational occurrences and accidents (→ Article 19 (iv), page 170), 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, the deputy. 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 NHB and the testing manual. The safety requirements are contained in the following safety standards of the KTA:

- safety standard KTA 1201 “Requirements for the Operating Manual”,
- safety standard KTA 1202 “Requirements for the Testing Manual”, and
- safety standard KTA 1203 “Requirements for the Emergency Manual”.

Operating manual (BHB)

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:

- 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
- 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
- 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
- Systems operation
  Instructions for operational processes of all systems under specified initial conditions or operating conditions
- Alarms
  Alarm signals from failures/malfunctions and hazardous conditions and the corresponding system-related actions initiated automatically or to be triggered manually
- 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 fundamental 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 ISIs) 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 to 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 ISIs 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 ISIs. 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.

Regulatory supervision

The competent 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. Findings from inspections and surveillance are evaluated and appropriate measures are taken to restore the required condition of the installation.

According to § 7 AtG, the licence holder is required to continuously adapt the safety precautions of the installation in accordance to the advancing state of the art in science and technology.

An obligation to review maintenance strategies and measures by the competent licensing and supervisory authority derives from the SiAnf and the subordinate nuclear rules and regulations (e.g. safety standards of the KTA, 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 in the AtSMV. The substatutory SiAnf 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 fundamental safety functions. These are:

control of reactivity (subcriticality),

fuel cooling (in the 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 fundamental safety functions are repeatedly checked and the approach chosen adjusted if appropriate.

Specific parameters of the installation are assigned to each fundamental safety function. Should compliance with any of the fundamental safety functions 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 an 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 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 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 (→ Article 16, page 134134).

In addition to the existing NHB, an 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[49]. The procedures and strategies contained in these manuals comply with the international recommendations on SAMGs.

Regulatory supervision

An essential tool of nuclear supervision of the nuclear installations is the handling of events. Reporting of events by the licence holders to the competent 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 competent licensing and supervisory authority. An event in a nuclear installation is reportable if it meets the criteria specified in Appendix 1 AtSMV (→ Article 19 (vi), page 173).

According to the AtSMV, 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 (→ Article 19 (vi), page 173). 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.
- Maintenance:
  Planning, control, performance and surveillance of maintenance measures, technical modifications and backfitting measures

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[49] Finalised action plan for the implementation of measures following the reactor accident in Fukushima, BMUB, December 2017, www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/aktionsplan_fukushima_bf.pdf

- 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 competent licensing and supervisory authorities of the *Länder* 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 competent licensing and supervisory authorities and their experts obtain highly detailed knowledge about the status of the nuclear installations under supervision.

In addition, BMUKN deals with generic and internationally safety-relevant issues. The corresponding 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 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 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 competent licensing and supervisory authorities in the enforcement of the AtSMV and ensuring a uniform enforcement of the AtSMV by the competent regulatory authorities of the *Länder*. Therefore, the explanatory notes are continuously improved and adapted.

A reportable event is to be notified to the competent 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 competent licensing and supervisory authority of the *Land* in turn reports the event to the Incident Registration Centre at BASE as well as to BMUKN and GRS. The reportable events are evaluated by the licence holders, authorities, authorised experts and – in so far as necessary – also by the manufacturers.

BASE informs all competent 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 BASE is accessible to the nuclear licensing and supervisory authorities of the *Länder*, BMUKN 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 competent 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 competent 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.

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
2024	29	0	0	29	29	0	0
2023	36	0	0	36	36	0	0
2022	43	0	0	43	43	0	0
2021	39	0	1	38	39	0	0
2020	63	0	0	63	63	0	0
2019	50	0	2	48	49	1	0
2018	76	0	0	76	76	0	0
2017	53	0	2	51	53	0	0
2016	70	1	0	69	69	1	0
2015	60	0	2	58	60	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.

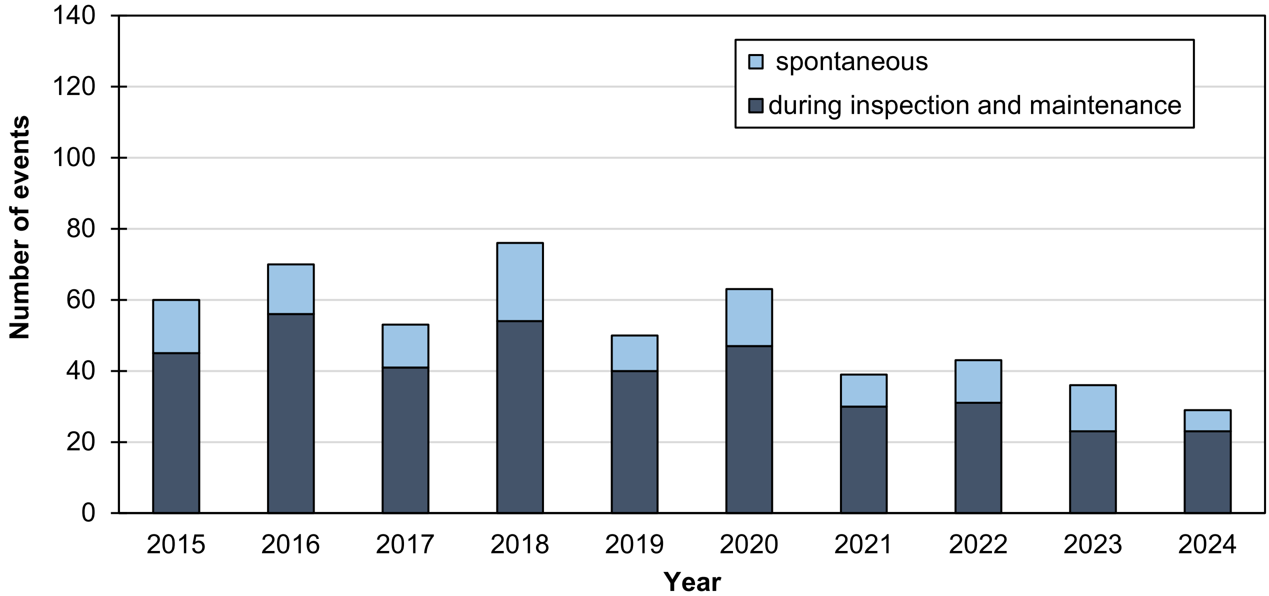

Figure 19-1 Reportable events from nuclear installations for electricity generation according to the type of occurrence

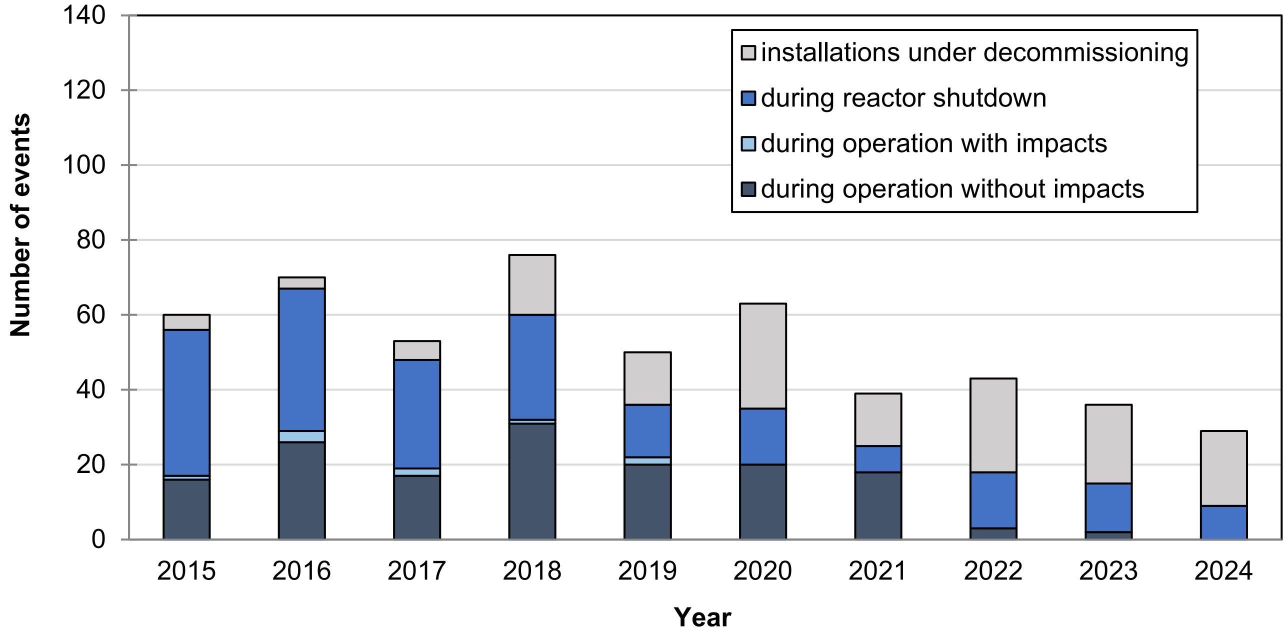

Figure 19-2 **Number of reportable events from nuclear installations for electricity generation according to mode of and impacts on operation (power operation, start-up and shutdown operation)**

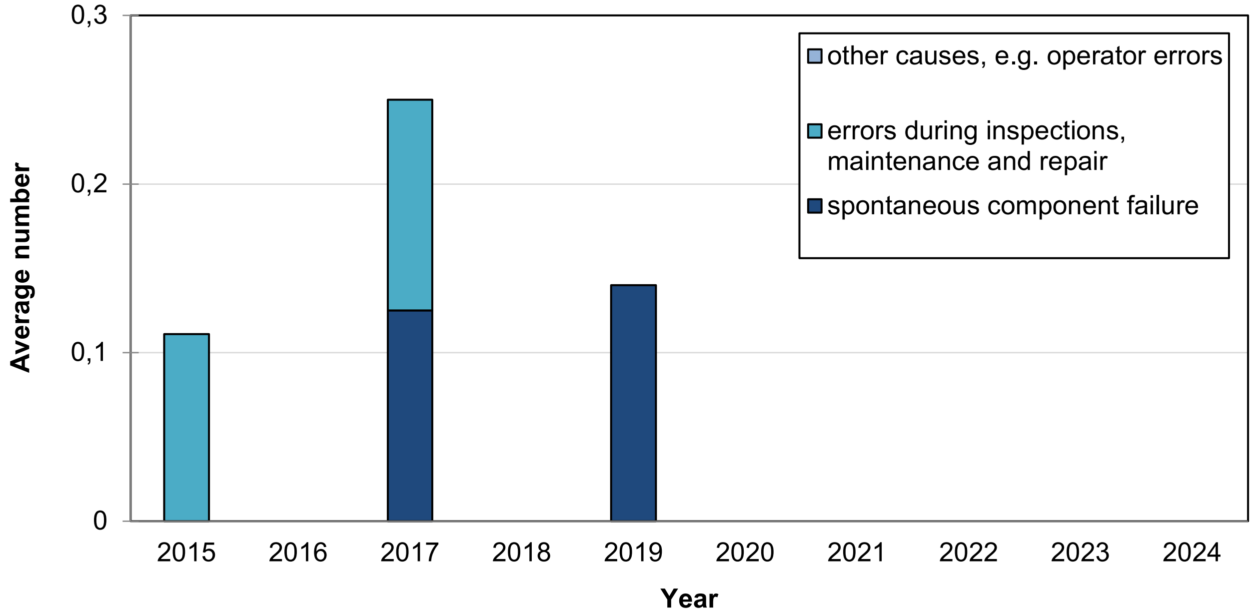

Figure 19-3 **Average number of unplanned reactor scrams per installation and year**

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 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 BMUKN.

Regulatory supervision

If the competent 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 competent licensing supervisory authority, usually with the participation of authorised experts according to § 20 AtG. If necessary, the competent licensing and supervisory authority specifies further remedial measures and the precautions to be taken.

The complete and final report on a reportable event shall be submitted to the competent supervisory authority as soon as the missing data are available but no later than two years after the event, unless the authority has agreed to a later submission. According to § 9 AtSMV, the safety officer is obliged in the case of reportable events, to take measures for the preservation of evidence (safekeeping of defective parts, taking of photos and the preparation of a comprehensive documentation of the defects) that allow later traceability and verification of the event causes and consequences. In addition, reports are requested from the licence holder by the supervisory authority and the expert organisations to analyse the causes and measures against recurrence of the event.

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), page 173),
- 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 SMS 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 root cause analysis is performed. For this purpose, the contributing factors from the areas of MTO and their interactions are taken into account. To carry out the analysis, in 2014, the RSK has developed a guideline for the performance of root cause analyses, which has been applied by the German licence holders of nuclear installations after consultation with vgbe since 2015.

With the so-called Central Incident Reporting and Evaluation Office of vgbe (vgbe-ZMA), the licence holders have an own database for the exchange of generic information. The vgbe-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 vgbe-ZMA is being a connecting point to the international reporting system of the 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 vgbe-ZMA as well as to WLNs and reports of the IRS. The applicability and relevance to German nuclear installations is checked and the results for the plant components supplied by the Framatome GmbH are communicated.

The plant managers and other specialist experts are organised in VGB working groups and committees and exchange more experiences at this level.

National and international evaluation of operating experience on behalf of BMUKN

The national Incident Registration Centre is organised at BASE. BASE 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 BMUKN in monthly reports. The database of reportable events is accessible to the competent licensing and supervisory authorities of the *Länder*, BMUKN and GRS. The current reportable events are discussed in the committees of the RSK on the basis of the monthly reports of BASE.

On behalf of BMUKN, GRS evaluates the national and international operating experience on a holistic basis, partly involving further independent expert bodies (Öko-Institut e.V. and Physikerbüro Bremen). In particular, the international events reported within the IRS of the IAEA and in the EGOE of the 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 BMUKN 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 BMUKN. These are released by BMUKN and transmitted by GRS to the competent 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

- 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 is obliged (e.g. by licence conditions) to prepare a statement for the competent 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 competent supervisory authority examines this statement (usually with the help of authorised experts) to determine whether the measures are sufficient for implementation or whether further measures need to be taken. The plant-specific results of the information feedback are then reported to BMUKN by the competent 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 the supervision manual 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[50] 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 competent 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:

- <u>Replacement of pipes in the main steam and feedwater systems of BWRs both inside and outside of the containment</u>
  Originally, the main steam and feedwater pipes were made of a steel with relatively high strength and therefore low wall thickness. This led to problems due to the quality of the pipes and misalignment at the welds. During operation, cracks due to strain corrosion cracking were observed at the weld imperfections. The pipes were replaced in the 1980s with pipes of higher wall thickness and less strong steel.
- <u>Backfitting of diverse pilot valves in the overpressure protection system of BWRs</u>
  Diverse valves have been installed in BWRs to allow pressure to be limited in the event of failure of the main valves during accidents. In addition, these pilot valves can be used during certain normal operating conditions, which improves pressure control due to their smaller cross-sections compared to the main pressure relief valves.
- <u>Conversion of all PWRs to high-AVT (all volatile treatment) of the secondary-side water chemistry</u>
  The secondary-side water chemistry of PWRs originally used phosphate as an alkalising agent, which resulted in the loss (laminar wall thinning) of the steam generator tubes. To

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50 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.

avoid this, water treatment with a high AVT content was gradually introduced in all installations in the 1980s, aiming at a pH of > 9.8 in the entire circuit. This water chemistry caused no wastage and effectively suppressed erosion-corrosion. As a precondition, all heat exchangers with brass tubes in the secondary circuit had to be replaced since brass corrodes selectively at this pH value.

- Fabrication of weld seams for better testability with ultrasonic procedures by machining the weld surfaces as well as rewelding of seams of pipes and other components in PWRs and BWRs
  With the introduction of the basic safety principles in 1979, not only the primary (Class I) but also the weld seams of the secondary (Class II) pipes had to be ground smooth for diameters over 50 mm and even flat for diameters over 150 mm and wall thicknesses over 10 mm. Exceptions were made for austenitic welds if they were already smooth enough to allow the corresponding non-destructive tests. Following the requirement to provide testability, some welds were also rewelded in installations in operation if they were not suitable for the intended test, e.g. in the case of excessive root convexity breakouts. There were also other reasons for rewelding, such as suspicious ultrasonic signals, stress corrosion cracking (knife-line attack) on austenitic welds of some pipe in 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 BMUKN, the competent 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 the INES, Germany has reported four events in nuclear installations classified as INES Level 2. GRS immediately informs BMUKN 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 BMUKN to the *Länder* with nuclear installations. In addition, BMUKN informs the *Länder* about events classified as INES Level 2 in foreign nuclear installations in the Working Group Supervision of NPP Operation of the LAA.

Regulatory supervision

The procedures of the competent 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

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 respective bilateral commissions (→ Article 17 (iv), page 155).

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 spent fuel and radioactive waste

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 transfer of spent fuel from nuclear installations for reprocessing has been prohibited. The spent fuel is stored at the sites of the nuclear installations. After the amendment to the AtG in the course of the further development of the StandAG, the export of spent fuel from research reactors is only permitted for serious reasons of non-proliferation of nuclear fuel or for reasons of sufficient supply of FAs for medical and other top-level research purposes. An exception to this is the shipment of such FAs with the aim of producing waste packages that are qualified for disposal and that are to be disposed of in Germany. An export licence shall not be granted if the spent fuel is already stored in Germany pursuant to § 6 AtG.

The general principles for nuclear waste management in Germany are laid down in the national programme for the responsible and safe management of spent fuel and radioactive waste:

- The management of radioactive waste shall be carried out within German national responsibility and disposal shall take place on German national territory.
- The Konrad repository for radioactive waste with negligible heat generation and a repository according to the StandAG for heat-generating radioactive waste are to be established.
- Nuclear power plants whose authorisation for power operation has expired or whose power operation has ceased permanently and whose operators had to provide the payment for the fund in accordance with § 2(1) sentence 1 of the Waste Management Fund Act must immediately be shut down and dismantled, as defined in § 7(3) AtG. Thus, safe enclosure is no longer an option for such installations.
- It is planned that the construction of the Konrad repository will be completed by the end of 2029. The licensed waste volume amounts to a maximum of 303,000 m^3. Emplacement is scheduled to begin in the early 2030s with a planned operating time of approx. 40 years.
- According to the StandAG, the site for the disposal facility for heat-generating radioactive waste is to be determined by 2031 and the disposal facility is to be commissioned around 2050.

The management, financing and responsibility for decommissioning, dismantling and conditioning of radioactive waste lie with the licence holder, while the financing and responsibility for storage and disposal activities lie with the Federation. This is regulated in the Act on the Reorganisation of Responsibility in Nuclear Waste Management, which entered into force on 16 June 2017. The licence holders transferred a sum of 24 billion euros to the Federal Government, which was paid into a fund. To secure the financing of the costs, the Act on Transparency Regarding the Costs of Decommissioning and Dismantling of Nuclear Power Plants and the Packaging of Radioactive Waste (Transparency Act) and the Act on the Follow-up Liability for Dismantling and Waste Management Costs in the Nuclear Energy Sector entered into force on 27 January 2017.

Storage of spent fuel

Spent fuel is initially stored wet on-site in the spent fuel pools of the nuclear installations and then dry in the on-site storage facilities.

The safety-related design of the spent fuel pool and the fuel pool cooling system is geared to the effects of internal events such as reduced or failed heat removal, loss of coolant, failure of the energy supply, changes in reactivity, events during handling and storage of fuel assemblies as well as to natural or man-made external hazards.

Improvements in availability and reliability were achieved by adapting the operating regulations for the pool cooling system and the mode of operation of the cooling pipes. In addition to investigations to avoid cliff-edge effects, technical measures were implemented for beyond design basis accident scenarios, e.g. additional cooling and make-up options independent of river water and mobile power supplies.

These measures help to further reduce the extremely low frequency of damage to fuel assemblies in the spent fuel pool.

In the period from 1998 to 2000, the licence holders of the nuclear installations applied to BfS as the competent licensing authority for the licences required for the storage of spent fuel in on-site storage facilities (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 BASE. 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 mbH (BGZ) 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 SZLs is dimensioned such that all amounts of spent fuel and high-level radioactive waste from reprocessing can stored there until commissioning of a disposal facility. Storage 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 (SZLs) for spent fuel

SZL at the nuclear installation	Granting of 1st licence according to § 6 AtG	Capacity heavy metal [Mg]	Storage positions for casks (occupied end of 2024)	Start of construction	Date of 1st emplacement
SZL Biblis	22.09.2003	1400	135 (108)	01.03.2004	18.05.2006
SZL Brokdorf	28.11.2003	1000	100 (61)	05.04.2004	05.03.2007
SZL Brunsbüttel[51]	28.11.2003	450	80 (20)	07.10.2003	05.02.2006
SZL Grafenrheinfeld	12.02.2003	800	88 (54)	22.09.2003	27.02.2006
SZL Grohnde	20.12.2002	1000	100 (68)	10.11.2003	27.04.2006
SZL Gundremmingen	19.12.2003	1850	192 (137)	23.08.2004	25.08.2006
SZL Isar	22.09.2003	1500	152 (88)	14.06.2004	12.03.2007
SZL Krümmel	19.12.2003	775	65 (42)	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 (99)	17.11.2003	06.12.2006
SZL Philippsburg	19.12.2003	1600	152 (106)	17.05.2004	19.03.2007
SZL Unterweser	22.09.2003	800	80 (40)	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 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, are 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

[51] 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 licensing and supervisory authority has issued an order pursuant to § 19 AtG according to which the storage of the nuclear fuel is tolerated until an enforceable and usable storage licence pursuant to § 6(1) and (3) AtG is granted or a deviating order is issued.

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.

Germany is a contracting party to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The reports of the Federal Republic of Germany for the review meetings of the Joint Convention[52] 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 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

Report on the activities relating to spent fuel and radioactive waste management, the decommissioning of nuclear facilities and the management of disused sealed radioactive sources in Germany is given regularly within the framework of the National Report and the review meeting under the Joint Convention. The last, i.e. the 8th Review Meeting under the Joint Convention took place from 17 to 28 March 2025.

Clearance

The clearance levels for radioactive materials with minor activity and the procedures for clearance are specified in the StrlSchV, which defines for about 800 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 licensing and supervisory authority of the *Land*, which also performs control measurements.

Implementation of the “Vienna Declaration on Nuclear Safety”

In German nuclear installations, provisions have been made for an emergency organisation and a crisis management team already many years before the nuclear accident at Fukushima. These are

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52 “Report of the Federal Government for the Eighth Review Meeting in March 2025 on the fulfilment of the obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management”, BMUV, August 2024; https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Nukleare_Sicherheit/jc_8_bericht_deutschland_atomenergie_en_bf.pdf

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.

Appendix 1: Nuclear installations and experimental and demonstration reactors

Appendix 1-1: Nuclear installations and experimental and demonstration reactors under decommissioning

Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning Site		a) Last licence holder (operation) b) Manufacturer c) Holder of the decommissioning licence	Type Gross capacity MWe	a) First criticality b) Shutdown c) First decommissioning licence
1	**Gundremmingen Unit A (KRB A)** Gundremmingen Bavaria	a) Kernkraftwerk RWE-Bayernwerk b) AEG/General Electric c) RWE Nuclear GmbH	**BWR** 250	a) 14.08.1966 b) 13.01.1977 c) 26.05.1983
2	**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)
3	**Mehrzweckforschungs reaktor (MZFR)** Eggenstein-Leopoldshafen Baden-Württemberg	a) Kernkraftwerk Betriebsgesellschaft mbH b) Siemens/KWU c) Kerntechnische Entsorgung Karlsruhe GmbH (KTE)	**PHWR** 57	a) 29.09.1965 b) 03.05.1984 c) 17.11.1987
4	**Kompakte natriumgekühlte Reaktoranlage (KNK II)** Eggenstein-Leopoldshafen Baden-Württemberg	a) Kernkraftwerk Betriebsgesellschaft mbH b) Interatom c) Kerntechnische Entsorgung Karlsruhe GmbH (KTE)	**SNR** 21	a) 10.10.1977 b) 23.08.1991 c) 26.08.1993
5	**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)
6	**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)
7	**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
8	**Greifswald Unit 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

	Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning Site	a) Last licence holder (operation) b) Manufacturer c) Holder of the decommissioning licence	Type Gross capacity MWe	a) First criticality b) Shutdown c) First decommissioning licence
9	**Greifswald Unit 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
10	**Greifswald Unit 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
11	**Greifswald Unit 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
12	**Greifswald Unit 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
13	**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
14	**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
15	**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
16	**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
17	**Isar Unit 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
18	**Neckarwestheim Unit I (GKN I)** Neckarwestheim Baden-Württemberg	a) EnKK b) KWU c) EnKK	**PWR** 840	a) 26.05.1976 b) 06.08.2011 c) 03.02.2017
19	**Biblis Unit 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
20	**Biblis Unit 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

	Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning Site	a) Last licence holder (operation) b) Manufacturer c) Holder of the decommissioning licence	Type Gross capacity MWe	a) First criticality b) Shutdown c) First decommissioning licence
21	**Philippsburg Unit 1 (KKP 1)** Philippsburg Baden-Württemberg	a) EnKK b) KWU c) EnKK	**BWR** 926	a) 09.03.1979 b) 06.08.2011 c) 07.04.2017
22	**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
23	**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
24	**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
25	**Gundremmingen Unit B (KRB-II B)** Gundremmingen Bavaria	a) Kernkraftwerk Gundremmingen GmbH b) KWU c) RWE Nuclear GmbH	**BWR** 1344	a) 09.03.1984 b) 31.12.2017 c) 19.03.2019
26	**Philippsburg Unit 2 (KKP 2)** Philippsburg Baden-Württemberg	a) EnKK b) KWU c) EnKK	**PWR** 1468	a) 13.12.1984 b) 31.12.2019 c) 17.12.2019
27	**Gundremmingen Unit C (KRB-II C)** Gundremmingen Bavaria	a) RWE Nuclear GmbH b) KWU c) RWE Nuclear GmbH	**BWR** 1344	a) 26.10.1984 b) 31.12.2021 c) 26.05.2021
28	**Neckarwestheim Unit II (GKN II)** Neckarwestheim Baden-Württemberg	a) EnBW Kernkraft GmbH (EnKK) b) KWU c) EnKK	**PWR** 1400	a) 29.12.1988 b) 15.04.2023 c) 04.04.2023
29	**Grohnde (KWG)** Emmerthal Lower Saxony	a) E.ON Kernkraft GmbH b) KWU c) PreussenElektra GmbH, Gemeinschaftskraftwerk Grohnde GmbH & Co oHG, Gemeinschaftskraftwerk Weser GmbH & Co oHG	**PWR** 1430	a) 01.09.1984 b) 31.12.2021 c) 06.12.2023
30	**Isar Unit 2 (KKI 2)** Essenbach Bavaria	a) E.ON Kernkraft GmbH b) KWU c) PreussenElektra GmbH, Stadtwerke München GmbH	**PWR** 1485	a) 15.01.1988 b) 15.04.2023 c) 21.03.2024
31	**Krümmel (KKK)** Krümmel Schleswig-Holstein	a) Kernkraftwerk Krümmel GmbH & Co. oHG b) KWU c) Kernkraftwerk Krümmel GmbH & Co. oHG	**BWR** 1402	a) 14.09.1983 b) 06.08.2011 c) 20.06.2024

Nuclear installations for electricity generation and experimental and demonstration reactors under decommissioning Site		a) Last licence holder (operation) b) Manufacturer c) Holder of the decommissioning licence	**Type** Gross capacity MWe	a) First criticality b) Shutdown c) First decommissioning licence
32	**Emsland (KKE)** Lingen Lower Saxony	a) Kernkraftwerke Lippe-Ems GmbH b) KWU c) RWE Nuclear GmbH	**PWR** 1406	a) 14.04.1988 b) 15.04.2023 c) 26.09.2024
33	**Brokdorf (KBR)** Brokdorf Schleswig-Holstein	a) PreussenElektra GmbH b) KWU c) PreussenElektra GmbH, Kernkraftwerk Brokdorf GmbH & Co. oHG	**PWR** 1480	a) 08.10.1986 b) 31.12.2021 c) 23.10.2024

Appendix 1-2: Nuclear installations 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	**Versuchsatomkraftwerk 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 1-3: Abandoned projects

	Abandoned projects Site	**a) Last licence holder** **b) Manufacturer**	**Type** Gross capacity MWe	**Status**
1	**Greifswald Unit 6 (KGR 6)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau	**PWR (WWER)** 440	Project abandoned
2	**Greifswald Unit 7 (KGR 7)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau	**PWR (WWER)** 440	Project abandoned
3	**Greifswald Unit 8 (KGR 8)** Lubmin Mecklenburg-Western Pomerania	a) Energiewerke Nord GmbH b) VEB Kombinat Kraftwerksanlagenbau	**PWR (WWER)** 440	Project abandoned
4	**SNR 300** Kalkar North Rhine-Westphalia	a) Schnell-Brüter Kernkraftwerksgesellschaft b) Interatom/Belgonucléaire/Neratoom	**SNR** 327	Project abandoned 20.03.1991
5	**Stendal Unit A** Stendal Saxony-Anhalt	a) Altmark Industrie b) VEB Kombinat Kraftwerksanlagenbau	**PWR (WWER)** 1000	Project abandoned
6	**Stendal Unit B** Stendal Saxony-Anhalt	a) Altmark Industrie b) VEB Kombinat Kraftwerksanlagenbau	**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 Labor für Strahlungsmess-technik	**SUR-100** $1\cdot10^{-7}$ $6\cdot10^{6}$	28.06.1973
2	**SUR-S** Stuttgart Baden-Württemberg	Universität Stuttgart Institut für Kernenergetik und Energiesysteme	**SUR-100** $1\cdot10^{-7}$ $6\cdot10^{6}$	24.08.1964
3	**SUR-U** Ulm Baden-Württemberg	Technische Hochschule Ulm Institut für Strahlenmess-technik	**SUR-100** $1\cdot10^{-7}$ $5\cdot10^{6}$	01.12.1965
4	**FRM II** Garching Bavaria	TU München	**Swimming pool/ compact core** 20 $8\cdot10^{14}$	02.03.2004
5	**FRMZ** Mainz Rhineland-Palati-nate	Johannes Gutenberg-Uni-versität Mainz Department Chemie	**Swimming pool/ TRIGA Mark II** 0.1 $4\cdot10^{12}$	03.08.1965
6	**AKR-2** Dresden Saxony	TU Dresden Institut für Energietechnik	**SUR type** $2\cdot10^{-6}$ $3\cdot10^{7}$	22.03.2005 (AKR-1: 28.07.1978)

Appendix 2-1b: Research reactors permanently shut down

Research reactors permanently shut down, no decommissioning 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	**FRG-1** Geesthacht Schleswig-Holstein	Helmholtz-Zentrum Hereon GmbH (formerly Helmholtz-Zentrum Geesthacht Zent-rum für Material- und Küs-tenforschung GmbH)	**Swimming pool/MTR** 5 $1\cdot10^{14}$	a) 23.10.1958 b) 28.06.2010 c) 21.03.2013
2	**FRG-2** Geesthacht Schleswig-Holstein	Helmholtz-Zentrum Hereon GmbH (formerly Helmholtz-Zentrum Geesthacht Zent-rum für Material- und Küs-tenforschung GmbH)	**Swimming pool/MTR** 15 $2\cdot10^{14}$	a) 16.03.1963 b) 28.01.1993[53] c) 21.03.2013[54]

53 Application for decommissioning and partial dismantling
54 Application for dismantling of the research reactor facility (consisting of the FRG-1 and parts of the FRG-2 still existing)

Research reactors permanently shut down, no decommissioning 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 decommissioning
3	**BER II** Berlin	Helmholtz-Zentrum Berlin für Materialien und Energie GmbH	**Swimming pool/MTR** 10 $2 \cdot 10^{14}$	a) 09.12.1973 b) 11.12.2019 c) 24.04.2017

Appendix 2-2: Research reactors under decommissioning

Research reactors under decommissioning Site		Licence holder	Reactor type Thermal output [MWth] th. n-flux [$cm^{-2}s^{-1}$]	a) First criticality b) Shutdown c) First decommissioning licence
1	**FR-2** Eggenstein-Leopoldshafen 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	TU 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	**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
6	**SUR-AA** Aachen North Rhine-Westphalia	RWTH Aachen, Institut für elektrische Anlagen und Energiewirtschaft	**SUR-100** $1 \cdot 10^{-7}$ $6 \cdot 10^{6}$	a) 22.09.1965 b) since 2002 out of operation and since 2008 free of nuclear fuel c) 26.06.2020

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) Shut down** **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	TU 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	TU München	**Subcritical assembly**	a) 06/1959 b) 1968 c) 20.03.1998
11	**SUR-M** Garching Bavaria	TU 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) Shut down c) Decommissioning completed
13	**SUR-B** Berlin	TU 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) 03/2000
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

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) Shut down c) Decommissioning completed
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
27	**ANEX** Geesthacht Schleswig-Holstein	Forschungszentrum Geesthacht	**Critical assembly** $1 \cdot 10^{-4}$ $2 \cdot 10^{8}$	a) 05/1964 b) 05.02.1975 c) 01/1980
28	**NS OTTO HAHN** Geesthacht Schleswig-Holstein	Forschungszentrum Geesthacht	**PWR nuclear ship** 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
30	**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) 19.09.2019
31	**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 and free of nuclear fuel c) 18.09.2019

Appendix 3: Safety-related design characteristics, PWR and BWR

1. Reactor coolant pressure boundary

a.) 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	RPV, 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 RPV to reduce neutron fluence	

b.) Reactor coolant pressure boundary BWR

Design characteristics	Construction line 72
Recirculation pumps integrated in the RPV	Eight
Suitability of the construction for destructive testing	Yes
Construction	
– Seamless forged rings for RPVs	Yes, except: closure head, bottom head
– Seamless pipes	Yes
Materials	
– Ageing-resistant ferritic fine-grained structural steels	RPV, main steam and feedwater pipes
– Ageing-resistant stabilised austenitic steels	Pipes[55], 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[56]
Reduction of embrittlement from neutron radiation exposure	Special fuel management (low leakage loading)

[55] For KRB II: Only stabilised austenitic pipes are used.
[56] For KRB II: The break preclusion concept was approved by the competent authority with a modification licence.

2. Emergency core cooling

a.) 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	

b.) 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

a.) 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	Emergency core cooling and auxiliary systems
– Ventilation systems	One isolation valve each inside and outside of containment	

b.) 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

4.1 PWR

4.1.1 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	

4.1.2 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.	

4.2 BWR

4.2.1 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

4.2.2 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. Electrical power supply

5.1 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 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. Protection against external hazards

6.1 PWR

Design characteristics	Construction line 3	Construction line 4
Earthquake	Design of safety-relevant components in accordance with site-specific load assumptions	
Aircraft crash and blast wave	Design in accordance with rules and regulations (→ Article 17 (i), page 149), emergency systems integrated the safety systems	

6.2 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), page 149), emergency systems integrated the safety systems