The
Federal Government

Strategy for Competence Building and the Development of Future Talent for Nuclear Safety

This strategy was prepared jointly under the leadership of the Federal Ministry for Economic Affairs and Energy and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Imprint

Published by
Federal Ministry for Economic Affairs
and Energy (BMWi)
Social media, public relations
11019 Berlin
www.bmwi.de

Status
August 2020

This publication is available for download only.

Design
PRpetuum GmbH, 80801 Munich

Content

A. Foreword

The decision to phase out the use of nuclear energy[1] for the commercial generation of electricity by the end of 2022, the reorganisation of responsibilities in nuclear waste management and the continued development of radiation protection have triggered significant changes in Germany in recent years. All carry with them a complex set of challenges. At the same time, nuclear energy will continue to be used in other countries for the generation of electricity in the years ahead. Even outside of power generation, the breadth and diversity of civil nuclear applications are growing, such as in materials testing or the production of radiopharmaceuticals. Examples of international developments include new fuel developments, advancements in the processing of radioactive waste and the use of neutron radiation for medicine, radiopharmaceuticals, industry and fundamental research. One of the central challenges Germany is facing is to preserve its vast reservoir of knowledge and experience, amassed over decades of research and practical applications in various fields of nuclear safety, for future generations and expand it appropriately as part of a state service of general interest. To safeguard German safety interests, broad and interdisciplinary expertise in these fields will remain necessary in the future.

Areas to be considered in this context are reactor safety, including the security, decommissioning and dismantling of nuclear facilities, nuclear waste management, including interim and final storage, and protection against ionizing radiation in these areas[2] (described as “nuclear safety” below).

At the national level, the emphasis is on the safe operation of the nuclear power plants that will continue to operate up until the end of 2022, the orderly decommissioning and safe dismantling of plants that have been shut down, and the safe management of spent fuel and radioactive waste. These challenges extend far beyond the year 2022.

With regard to radiation protection, research and development of innovative processes that involve the utilisation and generation of ionising radiation produce a constant demand for oversight by radiation protection experts both in industry (e.g. in material processing) and in medicine.

At the international and European level, the area of nuclear safety and security will play a dominant role for Germany even after the decommissioning of the German nuclear power plants, in addition to the aspects of nuclear waste management and radiation protection. Nuclear power plants in other countries in Europe and beyond will contribute to the supply of energy on the long term. In this context, lifetime extensions for existing facilities and the construction of new nuclear power stations, also involving new reactor concepts and the market launch of small modular reactors and micro-reactors in some cases, can be expected over the next few years. It is in Germany's own safety interests to follow global developments from a technical perspective, particularly with regard to existing and planned nuclear facilities in neighbouring countries, and to be able to influence the facilities’ safety and the preventive emergency preparedness measures put in place.

1 The following content refers exclusively to energy generation from nuclear fission.

2 In view of the mission set down in the Coalition Agreement (see below), radiation protection in medical therapy and diagnostics, in the industrial sector (outside nuclear technology) and in connection with natural sources of ionising radiation is not the focus of this strategy even though similar issues regarding the maintenance of skills and competencies arise in these areas and must be addressed in a separate process.

The importance of societal responsibility to maintain a safety-oriented system to develop German competence and future talent, and to continue to actively promote the German concept of safety at an international level is underscored by the following statement in the Coalition Agreement of the Federal Government of 14 March 2018:

> *"We will develop a strategy to maintain expertise and specialist personnel in the future for the operation and dismantling of nuclear facilities, for nuclear safety issues, and for interim and final storage."*
>
> (Lines 6677 to 6679)

> *"We want Germany to remain influential in the area of reactor safety in Europe – even after Germany's withdrawal from the national use of nuclear energy. [...] Those wishing to have a say in safety issues must have the relevant knowledge to do so. It is therefore essential to preserve the required expertise."*
>
> (Line 6681ff)

The importance of maintaining expertise and specialist personnel is underscored by various authorities and individuals. For example, as part of the Integrated Regulatory Review Service of the International Atomic Energy Agency, an international expert committee stated in its report in spring 2019 that the Federal Government *"should consider establishing a comprehensive plan, in consultation with relevant parties, for the project on German competence and financing needs during future decades."* Experts at the Helmholtz Association of German Research Centres (HGF) also stress that *"to maintain a world-class team in the future, the development and implementation of a sophisticated talent management strategy for succession is timely and crucial"*. The advisory bodies of the BMU and the Alliances for Competence in Nuclear Technology, Repository Research and Radiation Research regularly address the issue of maintaining expertise and specialist personnel.

B. Needs and objectives

Germany is facing manifold challenges in the field of nuclear safety:

- As Germany gradually reduces power plant capacities, compliance with strict safety standards and the maintenance of a high level of security must be ensured for the remaining time nuclear energy is used, in the post-operational phase, for the operation of research reactors, for the transportation of nuclear fuels and for the decommissioning and dismantling of nuclear facilities.

- Fuel elements and other radioactive waste must be placed in safe intermediate storage until deposited at a final repository.

- The safe and orderly management of radioactive waste resulting from the operation, decommissioning and dismantling of nuclear facilities and from the fields of medicine, research and industry is of paramount importance. Priorities in this respect include the planning, construction, operation and decommissioning of repositories and the continued development of the set of tools used to assess their operational and long-term safety.

- It is important to oversee the continued use of nuclear energy for the generation of electricity – irrespective of Germany's withdrawal from nuclear power – and its development in neighbouring countries and worldwide so that Germany can continue to actively contribute its understanding of safety to discussions on the safety of nuclear facilities at both the bilateral and multilateral level. Furthermore, this allows Germany to participate in the future development of international regulations and standards and the state of the art of science and technology. This also applies with regard to any emergencies at foreign nuclear power plants and other nuclear facilities.

- The effects of radiation on humans and the environment apply irrespective of action to phase out the commercial use of nuclear energy for electricity generation. Radiation exposure – either planned or due to an emergency situation – not only can occur during plant operation but also during the dismantling of nuclear facilities, and during the handling and storage of radioactive waste. Protection against ionising exposure situations, and medical and professional radiation protection in nuclear applications must be guaranteed.

- The recruitment of young talent and competence building are also essential to meet the needs of facilities and businesses that apply nuclear technology in areas outside of electricity generation, such as in the field of material research, nuclear medicine, radiopharmaceuticals, radiation therapy, radioecology, radiobiology, epidemiology, radiological protection technology, agriculture, foodstuffs, water management, industrial and IT applications, aerospace and the maintenance of cultural heritage.

To predict future demand for expert knowledge and specialist personnel in the field of nuclear safety, the Federal Government drew on the expertise of relevant stakeholders (licensing and regulatory authorities at Federal and *Länder* level, expert organisations, advisory bodies, utility companies, research institutes, higher education institutions (HEI) and industry). Their input has informed the development of this strategy. Furthermore, the Federal Government centred its work on international approaches, such as that defined in the International Atomic Energy Agency's (IAEA) Strategic Approach to Education and Training in Nuclear Safety 2013 – 2020[3].

To ensure the long-term preservation and continued development of the necessary expertise in Germany, it is essential to adopt measures that address the already existing shortage of skilled workers and the imminent loss of actively available knowledge and competence. These measures should be based on the following pillars:

- Retain and recruit qualified, skilled staff who contribute to addressing safety-related issues through their work at regulatory authorities, expert organisations, operating companies, producers etc.,
- Maintain and build expertise,
- Maintain teaching and research and develop content further,
- Knowledge management and knowledge retention, committee work and networking activities,
- Step up national and international networking and cross-border activities,
- Strengthen career prospects and recognition of the profession in society.

3 http://www-ns.iaea.org/downloads/ni/training/strategy2013-2020.pdf

C. Status quo/activities so far

Many of the Federal Government's ongoing activities address the topic of maintaining and building expertise and specialist capacities.

With its consistent funding of nuclear safety research, the Federal Government has made key contributions for many years towards maintaining, building and advancing scientific and technical skills and competencies, and towards fostering young talent in this field. These strategic goals are reiterated in the Federal Government's 7th Energy Research Programme of September 2018[4].

The promotion of excellent research projects is the focus of funding policy in the various domains and also helps the *Länder* to maintain and upgrade existing research capacities at German higher education institutions.

For example, project funding by the *Federal Ministry for Economic Affairs and Energy* (BMWi) towards reactor safety and nuclear waste management research, provided through the funding of research projects at HEIs, non-university research facilities and – to a lesser degree – in industry, make a central contribution to the advancement of the state of the art of science and technology and to training junior scientists. The Nuclear Waste Management, Safety and Radiation Research programme (NUSAFE) provides the framework for the Helmholtz Association of German Research Centres (HGF) for basic research on nuclear safety. The HGF centres FZJ (Jülich Research Centre), KIT (Karlsruhe Institute of Technology) and HZDR (Helmholtz Centre Dresden-Rossendorf) receive institutional funding, 90 % of which comes from the *Federal Ministry of Education and Research* (BMBF) and 10 % from the *Land* in which the institute is located. This basic research conducted by the HGF helps to continually advance the state of the art of science and technology and is essential for competence building and for training the next generation of scientists. With its funding concept "FORKA – Research for the Dismantling of Nuclear Facilities", the Federal Ministry of Education and Research has established a new framework for research projects on the decommissioning and dismantling of nuclear facilities and the management of resulting radioactive waste. Today's strategy therefore also helps to train the scientists and subject matter experts of tomorrow.

The project funding initiatives specifically geared towards the promotion of young scientific talent include the "Maintenance of Nuclear Competence" (KEK) initiative of the Federal Ministry for Economic Affairs and Energy and the funding announcement by the Federal Ministry of Education and Research, within the context of the 7th Energy Research Programme, in the field of nuclear safety research and radiation research[5], and support the retention of expertise and the training of young scientists and experts to address safety issues in nuclear technology.

Departmental research by the Federal Government establishes the decision-making basis for government action by pursuing problem-oriented, practice-based research and development. Within the sphere of responsibility of the Federal Ministry for Economic Affairs and Energy, the *Federal Institute for Materials Research and Testing* (BAM), the *Federal Institute for Geosciences and Natural Resources* (BGR) and the *National Metrology Institute (Physikalisch-Technische Bundesanstalt*, (PTB)) are entrusted with a variety of research tasks in the field of nuclear safety and also contribute to competence building and the promotion of young talent in this context.

4 https://www.bmwi.de/Redaktion/EN/Artikel/Energy/research-for-an-ecological-reliable-and-affordable-power-supply.html

5 Published in the Federal Gazette on 1/4/2019.

The future direction of departmental research under the jurisdiction of the *Federal Ministry for the Environment, Nature Conservation and Nuclear Safety* (BMU) is regularly reassessed in a dynamic process, also against the backdrop of retaining specialised knowledge. In this way, new challenges in the field of nuclear safety and radiation protection are identified early in a structured process. The BMU and its two subordinate authorities – the *Federal Office for the Safety of Nuclear Waste Management* (BASE) and the *Federal Office for Radiation Protection* (BfS) – are responsible for the administrative support and technical supervision of research projects. Furthermore, application-oriented research and studies are carried out by the government-owned companies *Bundes-Gesellschaft für Endlagerung mbH* (BGE) – the federal company for radioactive waste disposal – and *BGZ Gesellschaft für Zwischenlagerung mbH* (BGZ), which is responsible for interim storage.

At the national level, the various stakeholders exchange information and experience in a number of fora, including the *Alliance for Competence in Nuclear Technology* (KVKT), the *German Association for Repository Research* (DAEF) and the *Alliance for Competence in Radiation Research* (KVSF). The alliances for competence make a key contribution to maintaining and advancing subject matter expertise in the various fields and to safeguarding the scientific level on the long term through the promotion of young research talent in tandem with HEIs, non-university research centres, industry, policy-makers and associations.

Several committees are in place at the European and international level, particularly those of the EU/Euratom, the IAEA and the OECD/NEA. With representatives from public authorities, expert organisations, standardisation committees, research centres and the business community, Germany is actively involved in committee work dealing with conventions, rules and standards, in bilateral collaboration, knowledge-sharing and research networks. This work is central in promoting Germany's understanding of safety abroad.

Industry, commerce and service providers are involved in national and international nuclear safety research and contribute to competence development, the promotion of young scientific talent and the international debate. At the same time, they apply advancements in the state of the art of science and technology in concrete applications in Germany and abroad. This has enabled further insights and independent findings with regard to safety developments in other countries. In addition to the international networking of research, teaching, licensing and regulation, activities of German businesses abroad have provided an important platform for promoting Germany's understanding of safety in other countries and implementing it in practice.

D. Areas of action

An analysis of needs and activities currently in place identifies six areas of action on which measures to maintain and build expertise and specialist capacities should be focussed:

I. Education and teaching,

II. Advanced and continuing training,

III. Research and development,

IV. Knowledge retention, committee work and networks,

V. International networking and cross-border activities,

VI. Career prospects and recognition in society.

There is some overlap between the different areas of action, with the result that need for action identified in one area can directly or indirectly impact another action area. This must be considered in the overall design of the individual areas of action. With regard to the recommendations identified for the areas of action, the Federal Government is aware that some of the areas concerned do not fall within its remit and appreciates that the decision to introduce potential measures rests with the specific stakeholders concerned.

I. Education and teaching

Professional qualifications are key to preserving knowledge on the long term and to recruiting skilled personnel. A professional qualification guarantees the acquisition and advancement of skills that can be applied in the broad spectrum of tasks for the continuous improvement of nuclear safety. Given the sensitive nature of the tasks and the need to guarantee the utmost degree of safety, very high quality standards apply for professional qualifications in these fields. This high standard must continue to be maintained in the future, not least owing to legal commitments and German safety interests.

A vocational training programme and/or a degree course at a higher education institution teaches the skills, knowledge and information that are designed to enable future staff at all levels – both specialists and teachers at HEIs – to enter a specific professional field.

Research and teaching at HEIs play a central role in the recruitment of young talent. The provision of attractive teaching and research conditions can motivate students to specialise in subjects in the field of nuclear technology, including further qualifications in these areas. This requires the early involvement of students in research, an international orientation of their study programme and the availability of top-quality technical and scientific infrastructures. To this end, the development and implementation of suitable programmes in tertiary education and the further development of centres of excellence must be supported in line with needs. Competencies and expertise at university faculties in the field of nuclear safety should be maintained and developed further to the extent appropriate. This will depend largely on the availability of an adequate faculty infrastructure, e.g. also in the field of radiochemistry.

To promote the practical relevance of instruction and to foster early communication with young talent, action should be stepped up to provide teaching positions, particularly at departmental research institutes, and joint appointments of professors at neighbouring HEIs. With a view to gaining practical experience and connecting with potential employers, it is also necessary to increase the opportunities for students to complete examinations, such as PhDs or master's theses, in collaboration with businesses and public authorities, with the universities retaining responsibility for assessing the quality of the PhD papers. The promotion of exchange and mobility programmes for students and junior scientists can help create a more international training programme. Experts outside of Germany should also be specifically targeted for appointments.

Successful prior education in schools and other educational facilities is the basis for these training and education activities. In addition to teaching the fundamentals in STEM subjects (science, technology, engineering and mathematics), the priority here is for subjects related to humanities and social sciences to also teach the societal implications and relevance – be that with regard to the waste management tasks to be solved at national level, or with regard to the representation of Germany's safety interests in the context of the use of nuclear energy in other countries.

When they enter the orientation phase, school-leavers have a variety of ways to opt for occupations requiring formal training (vocational occupations) or a degree course to work in the field of nuclear safety in their chosen career, such as at a public authority, an operating company, an expert organisation, a producer or in research. This also includes specialisations and additional or further qualifications as part of a vocational training programme or degree course, as well as non-technical degree courses in the field of law and social sciences. The same is also true for the training sector and the dual system of vocational training and education as an important basis for ensuring the future supply of skilled labour. The **table provided in the Annex** indicates the broad range of vocational occupations and degree courses that are generally to be covered here.

Naturally, measures are not required in areas in which there is generally a strong demand for vocational occupations or study disciplines and therefore a sufficient supply of programmes on offer (e.g. studies in humanities). It is a different situation, however, if the training opportunities available do not, or no longer, suffice to cover existing or predicted future demand. The analyses conducted identify shortfalls – either now or in the near future – for a number of vocational occupations and degree courses. Specifically, this concerns professions and degree programmes listed in the **table in the Annex**.

Recommendations for the *education and teaching* area of action

1. Maintain and develop the substance of appropriate scientific and technical infrastructures at HEIs and research facilities.

2. Maintain and develop the substance of appropriate study courses at universities and universities of applied sciences.

3. Maintain and develop the substance of systems to adequately promote research projects at universities to attract young scientists through involvement in attractive research work in the field of nuclear safety.

4. Incorporate specialised topics of nuclear safety into degree programmes for STEM disciples, medicine, architecture, civil engineering or environmental engineering, for example; create opportunities for professional specialisation and skills development (e.g. by developing trainee programmes or additional and further qualifications).

5. Strengthen alliances between HEIs and operators, businesses, project promoters, departmental research institutes, licensing and regulatory authorities by mentoring and supporting final dissertations, internships and research or teaching projects, for example.

6. Develop and expand cooperation with local chambers of commerce and industry and with private training and educational facilities; incorporate specialised topics of nuclear safety into existing training programmes that touch on these topics (e.g. in the construction sector) within the framework of the individual regulatory procedures.

7. Internationalise study programmes, promote international exchange and collaboration with research centres and businesses outside Germany.

8. Continuously examine the extent to which demand can be met by the current education and training infrastructure.

II. Advanced and continuing training

Good continuing training and an appetite for lifelong learning in every career phase become increasingly important when individuals are established in their profession or are searching for new career challenges, e.g. by switching to a new field. Advanced and continuing training allows professionals to get ahead in their career and set themselves new goals. As it is becoming increasingly difficult to recruit specialist staff in the field of nuclear safety, businesses and public authorities need to place advanced and continuing training high on their agenda and optimise relevant plans for such training within an organisation, or across organisations, by adapting further training measures.

The structural changes in the nuclear technology landscape in Germany mentioned at the start of this paper, and the continued development of radiation protection with the introduction of Germany's new radiation protection legislation, also have implications for supply and demand for initial, continuing and advanced training opportunities. This calls for systematic adjustments that are consistent with demand.

Recommendations for the *advanced and continuing training* area of action

9. Develop and coordinate a harmonised advanced/continuing training programme for authorities at Federal/*Länder* level.

10. Gear advanced and continuing training centres to future challenges.

11. Create and utilise modern learning platforms (e.g. for e-learning courses or live online training programmes, databases with training material).

12. Promote interinstitutional advanced training programmes. Develop advanced training programmes focussing on topics in the field of nuclear safety. Incorporate specialised topics into existing advanced and continuing training programmes in areas that touch on these topics.

13. Ensure fuller integration of international expertise in advanced and continuing training and closer collaboration with international partner organisations.

III. Research and development

Ongoing state-sponsored research and development is essential on the long term to retain and further develop technical and scientific expertise in the dynamically evolving fields of nuclear safety. This ensures that national and international safety and waste management strategies are independently examined, assessed and organised. Action that addresses diverging research approaches and findings at both national and international level is a key prerequisite to safeguarding scientific standards.

The retention of expertise and specialist staff responsible for safety questions that must be answered with regard to the operation and dismantling of nuclear facilities, the interim and final disposal of waste, and issues relating to radiation protection and radiation research is imperative. This serves to ensure that Germany remains influential in the field of nuclear safety in Europe and worldwide. This is also the objective of the promotion of research by the BMWi and the BMBF, which is committed to increasing scientific knowledge and is independent of operator interests, and includes the funding of projects that are directly geared towards junior research talent. Through its support measures, the Federal Government has made a key contribution in recent decades to the continued development of the state of the art of science and technology. The findings of such research have frequently been the catalyst for additional improvements in safety both in Germany and abroad. In future, the priority will be to enhance and refine government funding of research projects.

Furthermore, departmental research within the area of responsibility of the BMU particularly serves to cover the support and research needs required to perform the department tasks. It does this by providing the decision-making bases and tools for preparing, examining, further developing and implementing goals, instruments, programmes and strategies as well as national, supranational and international legal regulations and obligations. Similarly, research projects are responsible for ensuring that competence and skills from national operational expertise can be actively tapped even after the end of the commercial operation of nuclear facilities in Germany, e.g. for the provision of information for international databases and treaties. The competence and diversity of experienced research institutes in the relevant fields of expertise must continue to be ensured so that the BMU always has access to qualified experts who cover the full range of opinions on a long-term basis.

The Federal Government finances nuclear safety research at universities, non-university research facilities and industry through the instrument of project funding. This makes a key contribution to preserving much-needed diversity in the German research landscape in these areas, enhances the scientific impact of the funding programmes and, importantly, makes them more appealing for young scientists due to the additional research and career opportunities involved.

Building on the national research base, research funded by the BMWi and the BMBF must also have an international focus for reasons of cost-effectiveness and diversity, as it would otherwise not consistently meet its own minimum quality standards. Networking is essential if research is to benefit from a global knowledge base. It is therefore important for German scientists to remain mobile and for Germany to regularly host researchers from other countries. Research students should be involved at an early stage. Germany has established reliable frameworks for collaboration with numerous international partners, with collaboration taking place both at the level of governments, administrations and intermediaries and at the level of research organisations and higher education institutions. Aside from bilateral research partnerships, the promotion of research through Euratom and collaborations within the framework of the OECD/NEA and IAEA helps connect German research institutes internationally and facilitates access to European research infrastructures and developments. International research projects, in particular, are attractive for young professionals embarking on their career. It is therefore crucial to increase the participation of German institutions in international research alliances. Any bureaucratic and financial barriers to the participation of universities and other research institutes in EU-funded research projects must be removed.

In the field of research into ionising radiation, support is given to maintaining strong research – ranging from radioecology and radiation physics to radiobiology and radiation epidemiology – for risk assessment and preventive protection. Changed policy conditions as a result of the Repository Site Selection Act *(Standortauswahlgesetz)*, the extended interim storage of radioactive waste and the timeline for the identification of suitable disposal facilities and the safe final storage of nuclear waste put new demands on radiation research.

Repository research has been conducted in Germany for more than 50 years. As a result, the country has built up excellent, internationally renowned scientific expertise on the management of radioactive waste. Repository site selection in Germany, with equal and unprejudiced consideration given to all host rocks, poses new challenges for nuclear waste management research. Besides final disposal in deep geological formations, waste management research also involves specific preliminary measures as well as studies on the effects of the anticipated extension of interim storage times on waste and containers. The funding measures implemented by the Federal Government in recent decades have greatly contributed to creating the scientific and technical basis for future repository concepts and safety assessments. Germany has a well-funded scientific base covering a comprehensive range of topics and is home to internationally renowned research institutes in the field of nuclear waste management. A contributing factor to this is the consistent monitoring of and active participation in relevant developments abroad within the context of international cooperation.

The Federal Government's 7th Energy Research Programme provides a detailed account of the strategic objectives of research funding in the areas of reactor safety research, waste management research and radiation research.

The availability of an appropriate research infrastructure is a prerequisite for these research efforts. Large-scale research institutes and experimentation facilities, primarily of the HGF, and the corresponding infrastructures, as well as the continuation of research programmes for competence building and the recruitment of young talent play a central role in this respect. These infrastructures provide the basis for many university-based research projects and for safeguarding international quality standards in research. This includes the need for hot cells. With a national research infrastructure, a decisive influence on the content of the research programme can be retained and the complex transportation of radioactive specimen material abroad and dependency on foreign schedules can be avoided. In this context, the opening of national infrastructure facilities for international research alliances also helps promote open research infrastructures abroad.

Recommendations for the *research and development* area of action

14. Maintain and develop the substance of research funding by the Federal Government in the field of nuclear safety.

15. Maintain and develop the substance of the necessary national research infrastructure.

16. Strengthen closer collaboration on current research issues between HEIs and the users of the research findings and better networking among the central actors; make effective use of existing fora and develop new ones (research platforms and research alliances) to promote exchange between the scientific community, public authorities and operating companies.

17. Increase participation in European and international research alliances (e.g. within the framework of Euratom, OECD/NEA, IAEA, bilateral collaborations).

18. Foster the participation of German research-related facilities, particularly HEIs, in Euratom research projects; remove bureaucratic barriers to the joint financing of R&D activities through EU and national funding.

19. Maintain the diversity of national research institutes.

20. Maintain and refine the funding of research projects at universities in order to promote interest among junior researchers in nuclear safety topics by involving them in attractive research projects. This could also be accomplished through research projects in areas that receive less attention, such as nuclear forensics for example.

IV. Knowledge retention, committee work and networks

Germany has built up a wealth of knowledge in the field of nuclear safety over several decades. This is founded on a safety-oriented system that must always be aligned with the state of the art in science and technology. This knowledge is communicated through several channels, including committees and networks, at both the national, European and international level. Various alliances between public authorities or businesses (operating companies, producers, service providers), for example, ensure that safety-related issues are discussed, interfaces are investigated, responsibilities are concentrated, common approaches are agreed, experience is shared and decisions are made, all guided by the principle of the continuous improvement of nuclear safety.

Particularly in light of the phase-out of the use of nuclear energy for the commercial generation of electricity, operating companies that are required to decommission and dismantle their plants without delay at the end of commercial operation will only have a need for specialist knowledge and human resources for a limited period of time. This means operators will not retain the specialist knowledge they have of the operation of nuclear power plants over the longer term. Documentation and knowledge management systems should be established to also capture this knowledge on a long-term basis. Furthermore, it is also important to preserve an understanding of underlying reasons – the know-why – and pass this on to future generations of subject matter experts, e.g. via overlapping employee onboarding/offboarding or job shadowing at public bodies and research facilities.

Alongside this, work in committees and the communication of knowledge through networking have the task of establishing or maintaining functioning structures for knowledge retention and experience exchange, supporting interaction between the various actors, pooling resources and planning concrete measures. Many national networks and working alliances already exist in the individual areas of nuclear safety. The priority is to gear these to future tasks and responsibilities.

Recommendations for the *knowledge retention, committee work and networks* area of action

21. Pursue the further development of a systematic IT-based knowledge/document management system; set up a central literature/research database.

22. Develop existing networks of expertise further as appropriate.

23. Gear committee work to future tasks and responsibilities – including the provision of information to the general public.

V. International networking and cross-border activities

It is in Germany's interest that nuclear facilities both within Germany and abroad are operated to the highest possible safety standards. Given the cross-border nature of potential risks, this is a matter of protecting the population and the environment, and therefore a matter of public general interest in Germany. International consultation channels (particularly EU/Euratom, WENRA, IAEA, OECD/NEA) are used to be able to exert lasting influence on the safety standards applied in nuclear installations in other countries. Building on this, German regulatory authorities on international committees advocate the proper organisation of and adherence to safety standards. Germany also uses international consultation channels to have a say in issues concerning the non-proliferation of nuclear weapons and German defence and foreign policy, such as during the negotiation and implementation of the Joint Comprehensive Plan of Action (JCPOA). Germany can only continue to use these consultation channels if recognised expertise is available in the areas mentioned and young professionals can be recruited to this field.

The international networking of the activities of regulatory authorities, experts, research institutes and businesses that focus on the continuous improvement of international nuclear safety is imperative to ensure that Germany can make qualified contributions to, and remain influential in, the control, monitoring and design of nuclear safety in Europe and around the world. For this reason, not only national but also bilateral and international knowledge-sharing, advisory and standardisation bodies/committees and network structures play a very important role in nuclear safety issues. The same is true of the "lessons learned" process, which is particularly important in multilateral organisations such as the IAEA and the OECD/NEA or in Euratom.

Apart from the challenges of nuclear waste management and radiation protection, the field of nuclear safety and security will continue to rank high for Germany even after the decommissioning of Germany's nuclear power plants. Nuclear power plants will continue to play a role in energy supply in other countries in Europe and beyond over the long term. Lifetime extensions of existing plants and the construction of new nuclear power facilities, some using new reactor concepts, can be expected in the coming years. It is in Germany's safety interests to follow global developments from a technical perspective, particularly with regard to existing and planned nuclear facilities in neighbouring countries, and to be able to influence the facilities' safety and the preventive emergency preparedness measures put in place. The use of German safety technologies also plays a role in this context.

The provision of German goods and services can contribute to improving the safety of nuclear facilities abroad, help communicate Germany's safety philosophy and culture and apply it in concrete, real-life applications. This also facilitates the flow of feedback to Germany from practical applications abroad. It will be easier to continue this in the future if the businesses domiciled in Germany remain active on the international market. This will also be contingent upon the prevention of barriers to cross-border trade and transportation.

Actions to retain and build nuclear competence at technical support organisations in Germany (TÜV, GRS etc.) can only succeed if these enterprises can offer long-term career prospects. Collaboration in specific national and international projects plays an important role in this regard. These technical support organisations have amassed vast knowledge in the field of nuclear technology which should continue to be exploited.

Recommendations for the *international networking and cross-border activities* area of action

24. Cultivate committees and networks to ensure the international, multilateral and bilateral exchange of experience and knowledge, including active involvement in the development of safety requirements and standards in line with the state of the art in science and technology.

25. Guarantee German expertise in international committees/networks and ensure vacancies are filled seamlessly.

26. Support collaboration in international organisations (e.g. OECD/NEA, IAEA).

27. Prevent barriers to trade for businesses, products and services to enable international competitiveness.

VI. Career prospects and recognition in society

Interest in entering a degree programme or a vocational training course in the field of nuclear safety depends largely on the subsequent job prospects and how the job is recognised and valued in society. To retain and develop relevant competences in Germany, this will require varied and long-term career prospects at public authorities, in business enterprises, at expert organisations, research facilities (e.g. departmental research facilities, universities) and international organisations (IAEA, OECD/NEA). An infrastructure of state-run or government-funded institutions and an attractive range of jobs at public authorities and in business enterprises are central to maintaining and creating jobs in Germany.

Given the already noticeable competition for skilled workers in technical and scientific disciplines, employers in nuclear safety also need to offer attractive working conditions to recruit talented staff and retain them on the long term. The general framework in this sector that deals with complex, interdisciplinary issues, and its distinct international orientation, offer very good conditions in this respect. Furthermore, apart from a competitive salary an attractive working environment with good opportunities to reconcile family and work commitments is also a critical factor for many young professionals when choosing their career. At the same time, appreciation in society for the work performed in this field is of crucial importance. To this end, it is important to clearly communicate that the goal of professions in this field is to ensure the highest degree of safety. It is also important to stress the continued long-term demand for expert knowledge and qualified professionals despite the agreed withdrawal from the use of nuclear energy for the commercial generation of electricity and the changes associated with the energy transition.

Work and a career are of central importance for the integration and participation of young people in society. The smooth transition from school to a vocational training programme or a degree course is therefore all the more important. Occupations in the field of nuclear safety are multi-faceted and offer new opportunities to help address social challenges hands-on at the national, European and international level on a long-term basis. The Federal Government is constantly working to improve the foundations for vocational training and create equal opportunities. This also includes encouraging and supporting girls and young women in STEM disciplines.

The implementation of nuclear safety is part of a series of complex processes, performed by a variety of stakeholders with different interests, responsibilities and expectations. It is therefore important to also consider the social dimension when it comes to skills development and the recruitment of young talent. One factor in this respect is to encourage public interest in the various aspects of nuclear safety and recognise the value jobs in the field have for society.

Many of the research projects funded by the Federal Government in the field of nuclear safety are based on interdisciplinary collaboration and therefore help foster understanding of nuclear correlations and solutions to problems even outside traditional nuclear disciplines. An increasing focus is also on socio-technical issues, including the examination, modification and – where applicable – development of suitable processes for the continued development of technical expertise, the communication of complex subject matter, and participation. At the policy level, new approaches are being taken, such as with the Nuclear Site Selection Act. This gives the German population the opportunity to take an active part in the new process to identify a suitable site for the storage of high-level radioactive waste and gain a comprehensive insight into the complicated processes that authorities, operating companies, experts or producers must adhere to.

Dialogue between actors in the scientific and non-scientific field can foster interest in a profession in the field of nuclear safety and contribute to the recognition of such work in society. A key prerequisite for this dialogue is that research findings are processed and communicated for the scientific community on the one hand and for the interested public on the other. The organisation of symposia with separate sections for the public, for example, could provide an effective forum for dialogue.

Recommendations for the *career prospects and recognition in society* area of action

28. Hold awareness-raising campaigns to communicate the need to maintain qualified, subject-matter expertise in the fields of nuclear safety despite the energy transition and the decision to phase out nuclear power.

29. Develop an overarching communication strategy for public authorities, research and training institutions and businesses geared towards competence building and the recruitment of young talent in the areas of nuclear safety.

30. Improve the visibility of career prospects for new entrants to the workforce and people changing career from another discipline.

31. Support measures that seek interaction between parties involved in research into nuclear safety and the interested public; prepare the content of state-funded research for the interested public.

32. Introduce topics of nuclear safety into existing fora for the communication of science and technology, including educational institutions and museums of technology.

E. Assessment and outlook

The Federal Republic of Germany occupies a leading international position in the field of nuclear safety. The priority is to maintain this positive position on the long term and actively build on it so we can continue to address forthcoming tasks and challenges in this sector in observance of the highest safety standards.

Ongoing research funding is a key prerequisite to train the next generation of talent to perform the remaining nuclear tasks and impart and expand our know-how and know-why. This is why it is important to preserve the research infrastructure in Germany on the long term. International collaborations and cross-border activities in the scientific community and among public authorities and businesses, also with the transparent participation of the public, will continue to be necessary in the future to be able to obtain independent insights in Germany and help implement, in our best interest, the German understanding of safety nationally and abroad. Societal appreciation for the development of competence and young talent in the fields of nuclear waste management, reactor safety and radiation protection, which is relevant in this context, is central to effectively address existing or imminent barriers to the development of skills and young talent in the field of research and at public authorities, expert organisations and in the business sector. To this end, it is essential to consistently emphasise the foremost objective of enhancing nuclear safety and put this at the forefront of all activities.

With due consideration to current activities and existing structures in the field of nuclear safety, programmes geared towards the implementation of the recommendations set down in Section D should be modified or launched, if applicable. For the purpose of implementation, the government departments will conduct a detailed analysis of needs within their respective fields of responsibility. On this basis, they will define concrete measures to address these needs and implement them to the extent that funds available under the individual plans and human resources permit. This is therefore without prejudice to future budgetary procedures.

F. Implementation and evaluation

1. Within their respective fields of responsibility, BMBF, the BMU and the BMWi will take suitable measures to retain competence and skills and implement the strategy to the extent that funds available under the individual plans and human resources permit. This is therefore without prejudice to future budgetary procedures.
2. The strategy, the measures taken and the outcomes shall undergo review within five years at the latest.

G. Annex

The range of vocational training programmes or degree courses available is very broad, and it is often difficult for people to decide on the career that best suits their profile. It is therefore all the more important for individuals to receive adequate assistance in the decision-making process to gain a clear understanding of the options available for their future professional career. For the purpose of this strategy, the Federal Government conducted needs analyses and in doing so also identified the occupations requiring formal training and degree programmes that are needed in the field of nuclear technology. As in all professions, this is not set in stone and is subject to a certain degree of fluctuation, due, for example, to processes of structural change. The following **table** is therefore designed to serve as a reference. It not only lists the subject areas for which there is constant demand, both now and in the future, but also indicates in *italics* the professions that currently face shortages or are expected to face shortages in the future. The list is in alphabetical order.

Occupations requiring formal training
Building materials and mining: skilled construction worker, construction plant operator, *mining specialist (training as part of a relevant study programme), skilled mining worker* (e.g. heavy equipment mechanic, mining technician, drilling technician, hewer), *mining engineer, tunnel engineer*
Construction, surveying: mining surveying technician, geotechnician, pit surveying supervisor
Documentation & archiving: librarian, IT management assistant, administration
Electrics/electronics: electrician, electronics technician, computer scientist *(IT specialist for system integration and application development)*, instrumentation, control and telecommunications engineer, measurement engineer
Laboratory: laboratory technician (e.g. biological laboratory technician, medical-technical laboratory assistant), *medical-technical radiology assistant*
Metalworking, mechanical engineering: machine assembly technician, machinist/mine hoist operator, mechatronics technician, machinery technician, industrial mechanic, metalworking technician
Protection and safety: decontamination specialist, *nuclear technician*, master craftsperson for protection and safety, qualified protection and safety specialist, radiobiologist, *radiation protection specialist (vocational continuing training)*, radiation protection worker, process technician, environmental technician
Welding: *cask lid welder, welder*

Degree programmes
Engineering: plant engineering (e.g. fire safety, ventilation systems), industrial safety engineering, *civil engineering* (specialisation: ageing management), structural engineering, *mining engineering* (incl. tunnel construction), *mining surveying* (underground surveying), *chemical technology*, *electrical engineering* (e.g. instrumentation, control and telecommunications engineering), *geotechnical engineering*, *nuclear technology*, mechanical engineering, nuclear waste management, engineering physics, *testing and metrology*, *nuclear reactor technology* (incl. dismantling technology), residual materials and waste management, *radiation protection/safety technology*, safety engineering, environmental sciences (e.g. environmental engineering, environmental technology), process engineering, *material sciences*, industrial engineering and management
Humanities and social sciences: business studies, history, communications (including journalism), logistics management, management and safety management, media studies, political science (incl. participation research), psychology (including occupational and organisational psychology/sciences), *law (specialisation in mining law, nuclear law, radiation protection law and water law)*, social sciences, supply chain management, administration
Information sciences: *archive studies, library science/library management, data and knowledge management, documentation/documentation management, information management*
Natural sciences: biology, chemistry (e.g. building material chemistry, geochemistry, *radiochemistry*, environmental chemistry), *epidemiology*, geography, geoinformatics, geology (including *rock mechanics*, georesources management, hydrogeology, engineering geology), computer science (IT security, *numerical modelling and simulation*), mathematics (e.g. mathematical biology, statistics), *medicine* (e.g. nuclear medicine, radiology, radiation therapy), metallurgy, meteorology, *mineralogy*, physics (e.g. *nuclear physics, particle physics, reactor physics*, geophysics and medical physics)