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and Climate Action

Wismut

Mining remediation –
taking responsibility, shaping the future

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Content

Foreword

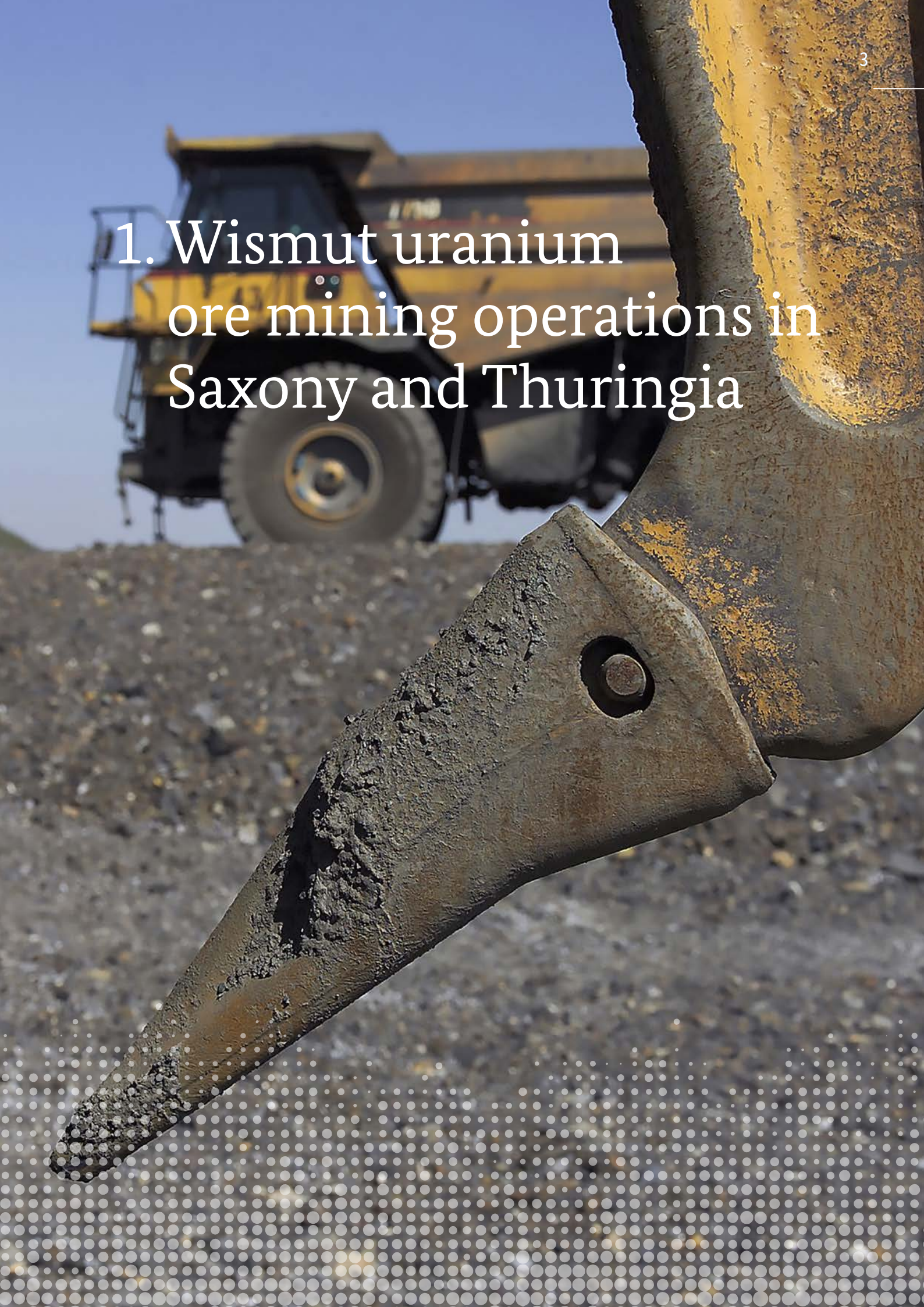
The federally owned company Wismut GmbH has been remediating the legacies left behind by former uranium ore mining and processing operations in Saxony and Thuringia for 30 years now. Upon German reunification in 1990, the Federal Republic of Germany assumed sole social and financial responsibility for this task and has provided funds totalling some seven billion euros to date.

The consequences of mining and the environmental impacts in the affected regions have visibly and significantly decreased. Remediation activities have mitigated environmental damage and reshaped natural landscapes for the benefit of the people of the region. The remediated land was and is essential not only to provide a habitable environment, but also to lay the foundations for positive regional and economic development, including use for forestry and agricultural purposes or for tourism.

The accomplishments of Wismut GmbH are highly regarded by the people in the affected regions and internationally. Its work is a recognised benchmark project for the remediation of radioactively contaminated industrial sites.

This brochure presents the initial situation and the results achieved thus far in the remediation of the mines and the remediation of former plant areas. It also provides an overview of the tasks ahead. Publishing this brochure is a token of gratitude for the successful work of the staff of Wismut GmbH, its partners and everyone else involved in the remediation process, and honours their achievements. At the same time, we would also like to thank all those who have made our work possible and supported us.

The Federal Ministry for Economic Affairs and Climate Action



1. Wismut uranium ore mining operations in Saxony and Thuringia

Schlema (1960)

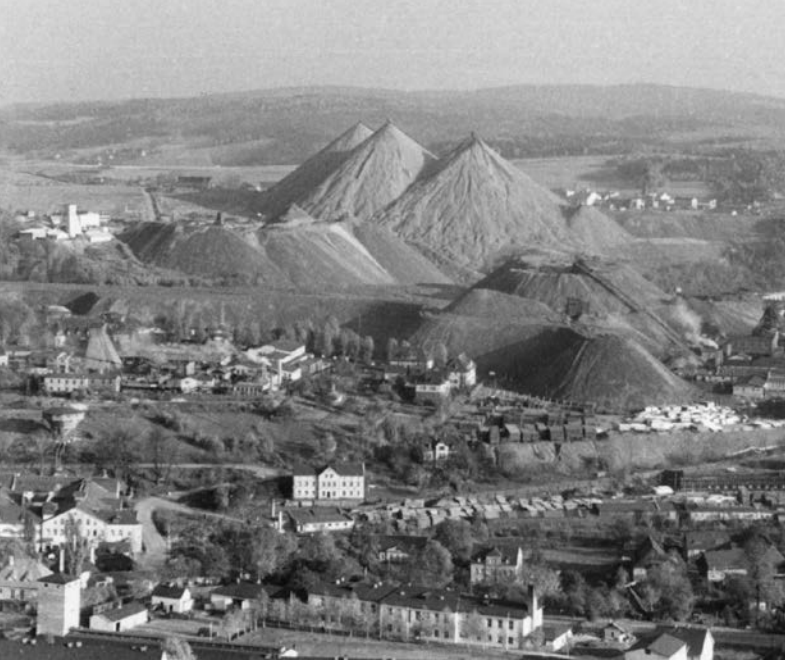
The legacies left behind by uranium ore mining were generated by more than 40 years of mining and processing of uranium ore in East Germany. As early as 1946, the then Sachsenerz Bergwerke AG started mining uranium ore from abandoned mine dumps, adits and shafts under the supervision of units of the Soviet army. To cover reparation claims, the mining companies operating in the former Soviet occupation zone were transferred to Soviet ownership. The Soviet stock company (SAG) Wismut was thus founded in 1947. The undertaking's goal was to provide uranium for the nuclear armaments programme of the former Soviet Union. To this end, a large workforce was recruited or, in some cases, conscripted from across the Soviet occupation zone to work in the uranium mines. Uranium ore mining and processing during this period was characterised by poor working conditions, complete disregard for nature and the environment, and insensitive encroachments on population centres. Vast swathes of land were confiscated and turned into prohibited zones: Wismut became a state within a state.

In 1954, the German Democratic Republic (GDR) was granted a stake in what had been a purely Soviet stock company up to that time, and the Soviet-German stock corporation (SDAG) Wismut was founded, with each partner holding 50 per cent of the shares. The basis for this change was an agreement signed between the governments of the USSR and the GDR on 22 August 1953. This agreement was revised in 1962 and extended in 1975.

Annual uranium production peaked at 7,100 tonnes in 1967. In 1990, production still amounted to some 3,000 tonnes. By the time uranium ore mining ceased on 31 December 1990, Wismut's plants had supplied a total of some 216,350 tonnes of uranium, making the GDR the world's fourth-largest uranium producer after the USSR, the USA and Canada.

Following German reunification, the Federal Republic of Germany and the Soviet Union signed a transition agreement on 9 October 1990. Under the provisions of this agreement, SDAG Wismut ceased its operations on 1 January 1991. This put an end to uranium ore mining in Saxony and Thuringia.

In 1990, the environmental situation in the mining regions was characterised by enormous environmental degradation affecting a total area of some 3,700 hectares, including radioactively contaminated waste rock piles, tailings management facilities and plant areas within a densely populated region. Mining activities had marked the mining and processing sites in Ronneburg, Seelingstädt, Crossen, Aue/Schlema, Pöhla, Königstein and Dresden-Gittersee (see Fig. 1, p. 7). Uranium mining operations had released radioactive materials into the atmosphere, soil and hydrosphere. In 1991, Wismut GmbH was responsible for more than 300 million cubic metres of mined material distributed across 48 waste rock piles. Processing the ore into yellowcake (a powdery mixture of uranium compounds) had generated more than 160 million cubic metres of tailings sludges containing residual levels of uranium and other contaminants. The situation in 1991 was such that it was imperative to initiate immediate action to eliminate hazardous risks, to close mines and pits in an orderly manner and to clean up and rehabilitate production sites.



Remediated waste rock piles in Aue-Bad Schlema are now hardly recognisable as such (2020)

Wismut GmbH – a federal responsibility

Under the terms of German unification, ownership of 50 per cent of the shareholdings of the binational company SDAG Wismut passed to the Federal Republic of Germany. The terms of the German-Soviet intergovernmental agreement of 16 May 1991 also provided for the transfer of Soviet shares to the German side. As a consequence, the Federal Republic assumed responsibility for the company as a whole. On 20 December 1991, the entry into force of the Wismut Act of 12 December 1991 transformed SDAG Wismut into a company under German corporate law: Wismut GmbH. Its sole shareholder is the Federal Republic of Germany, represented by the Federal Ministry for Economic Affairs and Climate Action (BMWK). Site decommissioning and remediation of uranium production legacies were defined as, and remain, the company's key mission and corporate purpose.

Following the usual practice in countries with planned economies, SDAG Wismut had not set aside any financial reserves for decommissioning and remediation work. The Federal Government therefore had to allocate sufficient funds to Wismut GmbH for the company to fulfil its mission.

The legal framework for the remediation work is set forth in the Wismut Act and other relevant regulations, laws and ordinances contained in German mining and radiation protection legislation in particular as well as in German soil protection and water legislation. Furthermore, it was necessary to allow two former GDR regulations containing specific provisions on the decommissioning of uranium mines (the Nuclear Safety and Radiological Protection Ordinance and the Mine Dump Ordinance) to remain in force under the provisions of the Unification Treaty. In addition, the German Commission on Radiological Protection has issued a number of radiological protection principles concerning the release of contaminated areas, waste rock piles, buildings and materials originating from uranium ore mining. These principles were taken into account when assessing the need to remediate areas and facilities and continue to form the basis for such decisions.

From a mining company to a remediation company

A priority task to be addressed in the early 1990s was the restructuring of the organisation from a mining company oriented towards the maximum production of uranium and operated under the conditions of a planned economy into a modern remediation company, acting in the private sector. On 1 January 1992, the numerous affiliated mine support activities of the former SDAG Wismut were split from the newly founded Wismut GmbH and privatised during the mid-1990s.

When uranium ore mining ceased at the end of 1990, there were no ready-made concepts or plans available to initiate the required pending remediation measures. Remediation concepts for all fields of activity therefore had to be developed at short notice. A prerequisite for this was the assessment of the existing environmental impacts and the establishment of an environmental register. The need for environmental remediation was identified, and specific remediation goals were defined, based on the analysis of this data. This also included carefully and comprehensively assessing the various options and alternatives from ecological, economic and social perspectives. This optimisation process also comprised considerations regarding the long-term stability and follow-up costs of the various possible solutions. Trade-offs between varied interests were negotiated in close cooperation with the responsible state supervisory authorities and through dialogues with municipal and district representatives of the affected areas.

This constructive cooperation with the regulatory bodies of the Free States of Saxony and Thuringia ultimately produced concepts that formed a safe and generally recognised basis for future remediation planning by Wismut GmbH. The decision-making processes always had to acknowledge that many remediation projects were intervention measures that have the capacity to mitigate environmental damage but cannot completely reverse environmental impacts. The first site-specific remediation concepts were finalised by August 1991 and then continuously updated based on growing expertise. They were and are the basis for the concrete design and planning of the individual remediation measures and for preparing the annual work programmes. Wismut GmbH submits all work projects to the responsible authorities of the Free States of Saxony and Thuringia for approval.

Due to the demanding nature and complexity of the tasks to be addressed, consultations with technical and scientific experts from Germany and abroad were required during the development of the concepts and the planning of the remediation activities. However, the project was unprecedented in global post-mining up to that point. It therefore called for many entirely new technical processes and methods to be developed.

Organisation and corporate structure

In the transition period between the Federal Government's assumption of responsibility and the founding of Wismut GmbH, the German side had already assumed managerial leadership as agreed during German-Soviet negotiations. The then Federal Ministry for Economic Affairs had appointed an advisory board for this transition period; this body would later act as a supervisory board. Upon the foundation of Wismut GmbH, the executive officers and a supervisory board were appointed. Until 2009, the shareholders and employees each had six representatives sitting on the supervisory board, equally represented in compliance with the 1976 Codetermination Act. Since 2009, the supervisory board has had nine members in accordance with the One-Third Participation Act.

Today, Wismut GmbH comprises the head office, based in Chemnitz, and seven remediation branches in Saxony and Thuringia (see Fig. 1). The corporate structure has been continuously adapted to the progress achieved in remediation in a bid to conduct remedial processes in a cost-effective manner.

Figure 1: Wismut-sites

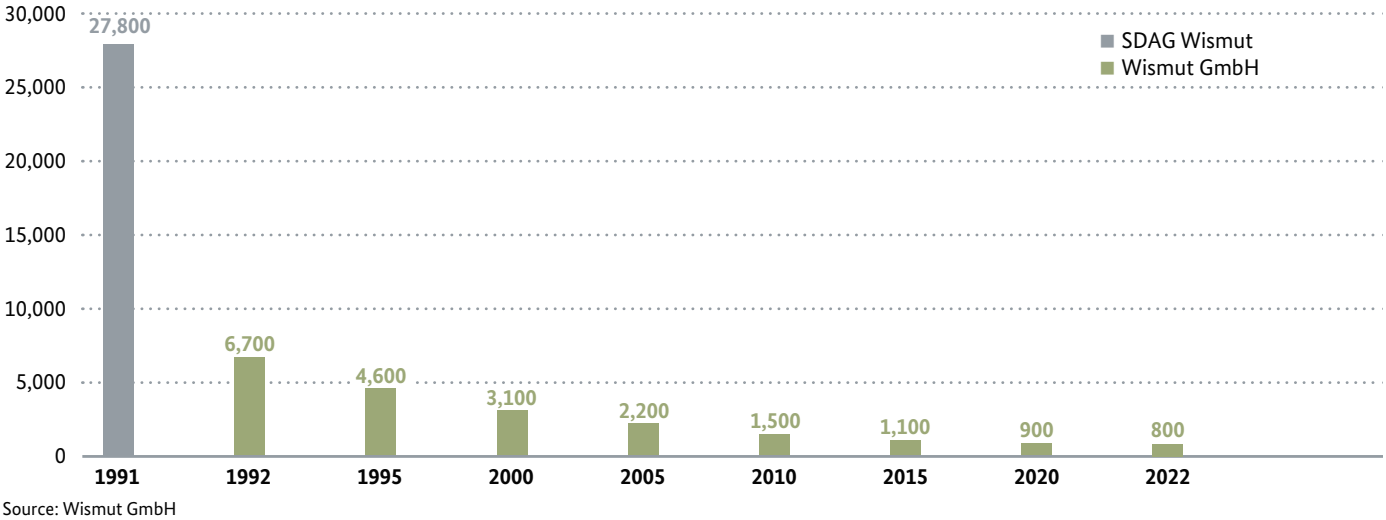
Funding

Upon German unification, the Federal Government not only assumed sole social responsibility for the remediation of the legacies left behind by uranium ore mining in Saxony and Thuringia, but also took on sole responsibility for financing the enormous tasks. In total, it is forecast that the Federal Government will have to provide 8.9 billion euros by 2050. By the end of 2022, some 7 billion euros had been spent – 3.7 billion euros in Thuringia and 3.3 billion euros in Saxony. The funding requirement is budgeted on the basis of the company's annual work plans, which are adopted as part of the federal budget by the German Bundestag.

Workforce development

One of the major problems to be solved during the early years following Unternehmenslethe terminatiitung on of uranium ore mining was to adapt the size and skills of the workforce to meet the challenge of the forthcoming remedial action. At the time when uranium ore mining and processing ceased, Wismut's workforce totalled almost 28,000 employees. Numerous jobs were lost during the initial years. Setting up two employment promotion schemes at the start of 1991 made it possible to streamline the production workforce in a socially acceptable manner. Close to 11,000 employees were supported through those schemes and participated in various employee development and retraining programmes. Following the spin-off of the mine support and auxiliary units on 1 January 1992, Wismut GmbH still had some 6,700 employees on its payroll. At the end of 2022, 800 remain (see Fig. 2).

Figure 2: Workforce development for Wismut GmbH from 1991 to 2022
Number of employees



Source: Wismut GmbH

Solar power plant and commercial use on the site of the former Beerwalde mining works and the remediated waste rock pile (2020)

That such drastic staff cuts could be implemented in a socially acceptable manner using various tools (employment promotion schemes, semi-retirement and miners' insurance compensatory payments) is a remarkable achievement that was made possible only by the good understanding among the parties involved – the Federal Ministry for Economic Affairs as the owner, the supervisory board, management, staff and IGBCE as the trade union for the mining, chemical and energy industries.

The main goals set for workforce development – to ensure the completion of remediation tasks to a high professional standard by experienced Wismut staff and to achieve a socially acceptable reduction in the workforce – have been fulfilled.

In addition to decommissioning and remediation projects, managerial tasks funded by the federal budget encompass the former employment promotion schemes, redundancy programmes and other personnel policy provisions for a socially acceptable reduction in the workforce as well as extensive educational opportunities for some 1,500 young people who have received training in a variety of trades.

Wismut as an economic factor

For almost 30 years, Wismut GmbH has been making a major contribution to creating and shaping improved living conditions and to the economic stabilisation of the former mining regions. Remediation of land has laid the foundations for attracting investors and for sustainable use, including the construction of solar plants, tourism projects and recreational opportunities as well as – and above all – the establishment of forest and grassland areas. By implementing these measures and its own remediation projects and by awarding extensive contracts – in particular to local companies – the company is securing existing jobs and creating new employment opportunities in the region. To date, Wismut GmbH has awarded third-party contracts totalling some 2.5 billion euros, including around 1.4 billion euros to contractors in Saxony and around 0.8 billion euros in Thuringia. These contracts primarily cover the purchase of materials and machinery, the supply of energy, raw materials, auxiliary and operating materials, the construction of facilities, and general and engineering services.

2. Remediation goals and concepts

The remediation work aims to remove the hazards to public safety, human health and the environment generated by uranium ore mining and its legacies or at least to diminish such risks to an acceptable residual level. An essential feature of the remediation of uranium mining is incorporating radiation protection considerations into almost all decisions. Remediation has restored an environment that is ecologically largely intact and fit for reuse. This is an indispensable prerequisite for the economic revival of the regions affected by Wismut mining operations.

Immediately after the cessation of mining, work began with extensive measures to protect the soil surface and eliminate risks. Comprehensive environmental studies were needed to determine further need for remediation or action and as a basis for drawing up the initial remediation concepts. The aim was to develop ecologically effective and sustainable solutions for the remediation of mines, waste rock piles and tailings management facilities as well as for the treatment of contaminated waters generated during and after remedial operations. What would happen to plant buildings, production facilities and plant areas was also up for decision.

Mine remediation concept

The remediation concept for underground mine workings in Ronneburg, Schlema-Alberoda, Pöhla, Königstein and Dresden-Gittersee calls for the flooding of the mines in conjunction with the remediation of near-surface mine voids. Shutting off the pumps that dewatered the mines during operation allows natural inflow of groundwater into the mines. Prior to initiating the flooding process, dams are built in the mines, and drifts backfilled. Plant and equipment, together with any oils, greases and chemicals present, are removed from the mine with a view to minimising subsequent contaminant release via the aquatic pathway. The rising flood water is systematically collected and treated in water treatment plants before being discharged into streams or rivers.

The backfilling of near-surface voids with concrete building materials is a further priority task in underground remedial action. The aim is to prevent ground subsidence and thus avoid risks for the population and damage to buildings. Shaft and adit openings must also be safely sealed.

Waste rock pile remediation concepts

Waste rock and overburden stockpiled in mine dumps resulted from the development of various ore deposits. Given their levels of naturally occurring radionuclides, their resulting specific activities are generally within a range that requires remediation for compliance with radiation protection legislation. Moreover, the overburden material often contains heavy metals that may be relatively easily mobilised, such as iron, nickel and copper; these must be prevented as far as possible from entering the groundwater and surface water. In addition, the slopes of many waste rock piles were too steep, and there was a real risk of slope failure. Safe remediation of the waste rock piles is therefore required under mining, radiation protection and water legislation.

Waste rock pile remediation follows two different strategies: relocation, which involves removal the overburden material and moving it to another location, and remediation in situ, whereby the waste rock piles are remediated in their current location. Which of the two strategies is followed in a given case is determined by site-specific conditions, cost-benefit considerations and public acceptance. Nearly all the waste rock piles at the Ronneburg site were relocated. The waste rock pile

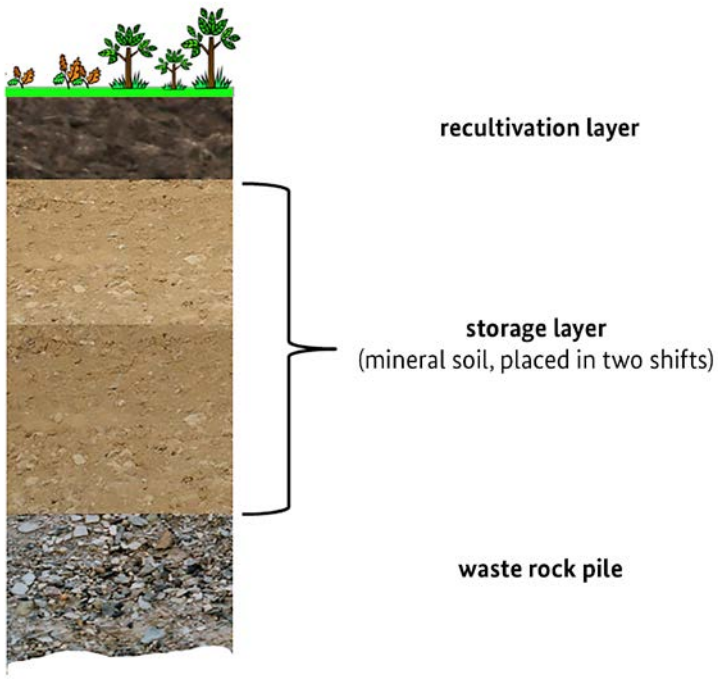
Remediation in situ of waste rock pile 310 in Bad Schlema (2014)

sites in Saxony on the other hand were almost without exception remediated in situ due to a lack of space or economic considerations. Mine dumps which contain waste rock and overburden materials suitable for covering purposes at tailings management areas constitute an exceptional case, and they are either partially or entirely relocated for placement on top of tailings management areas.

The basic remediation concept applicable to all waste rock piles provides for the enhancement of long-term slope stability and the covering of the piles with mineral- and vegetation-supporting soils. The covers have a number of functions to fulfil: They have to reduce infiltration of precipitation into the waste rock pile body in order to minimise the volume of contaminant-bearing seepage waters. In addition, the cover has to reduce the release of radon into the atmosphere.

In order to achieve the above goals, Wismut has developed various covering systems using different soil layers, depending on the location and purpose (see Fig. 3). These can be formed of topsoil, loamy soils, clayey soils or gravel-and-sand mixtures

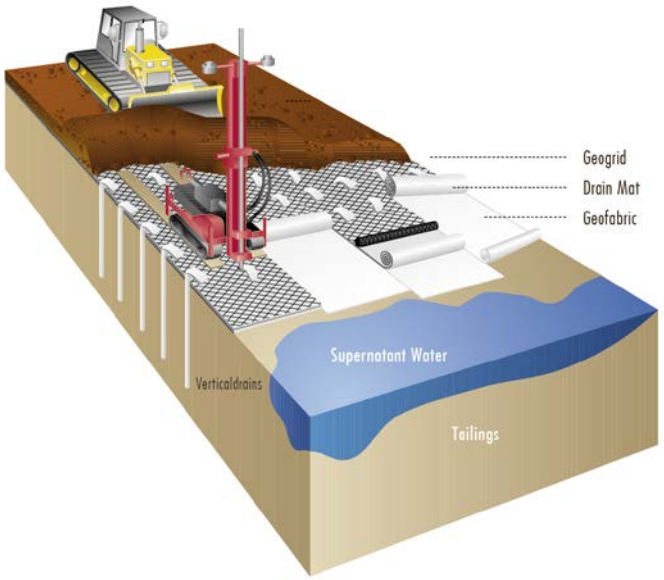
Figure 3: Standard two-layer mine dump cover, as exemplified by the design at the Schlema site



(which serve as drainage materials). Once the earthworks are completed, grass and herb mixtures are sown. This primary seeding serves as protection against erosion and stabilises the newly established topsoil layer.

Reclaimed waste rock piles and newly created landscapes have to be provided with access paths and draining ditches for the collection and discharge of surface run-off. The concept for the reuse of reclaimed waste rock pile surfaces generally provides for the establishment of a forest and meadow landscape. The fundamental principle followed when landscaping the reclaimed waste rock piles is to ensure that their contours and vegetation blend in with the surrounding environment.

Figure 4: Schematic diagram of the interim cover of a tailings management facility



Remediation concept for tailings management facilities

The residues generated during the processing of uranium ores at Seelingstädt and Crossen – also known as tailings – were deposited as slurries in the Culmitzsch, Trünzig and Helmsdorf/Dänkritz I tailings management facilities. Developing suitable stabilisation strategies was no easy undertaking due to lack of international experience remediating tailings ponds of such an order of magnitude. To establish an informed basis for decision making, scientific and technical preliminary studies and pilot scale tests first had to be performed; during the course of these investigations, the advice of international experts was also consulted. Ultimately, in cooperation with the regulatory bodies and their consultants, "dry" remediation in situ of the tailings with partial technical draining was identified as the preferred option, since it presented the optimum trade-off between environmental benefits and costs. On this basis, the remediation concept provides for the remediation in situ of all tailings management facilities. In the first step, the supernatant water is gradually removed from the tailings ponds and treated in water treatment plants. Finally, the exposed sludges are subjected to an additional technical drainage process, stabilised and finally covered.

The technology for covering these soft, liquid sludges (tailings), which are up to 70 metres thick, has largely been developed by Wismut itself. In a first step, a roughly 1.5-metre-thick interim cover, consisting of overburden material or sand and gravel, is placed on top of the exposed tailings surface. The superimposed load of the interim cover squeezes some of the pore water out of the fine-grained tailings; the expelled pore water rises along vertical drains (which have wicks measuring up to five metres long) drilled into the sludges and extending into the interim cover, from where it runs by gravity flow to the lowest point of the pond surface for collection, pumping and subsequent treatment. Covering the clayey-silty fine-grained tailings in the centre of the ponds presents a formidable challenge. The low load-bearing capacity of the subsoil does not allow direct place-

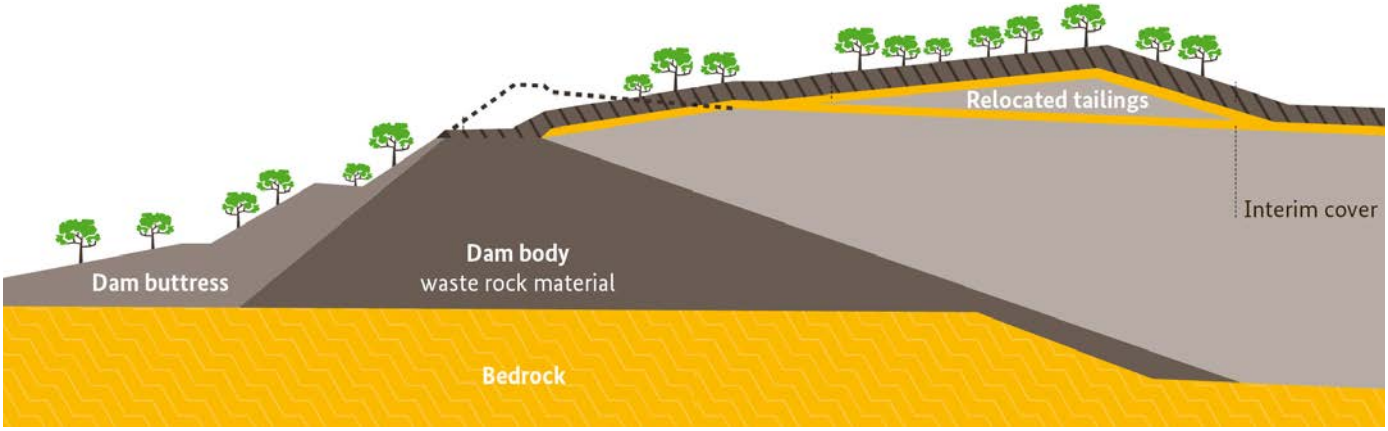
Final cover of part of pond A of the Culmitzsch tailings management facility, 2022

ment of the cover material. A geotextile primary covering, consisting of a non-woven geotextile and a geogrid, provides sufficient load-bearing capacity for the operation of low-weight equipment, thus enabling the driving of vertical drains and the placement of the interim cover (see Fig. 4). The interim cover gradually evolves into a load-bearing surface suitable for future remedial action.

The next remediation step is contouring. Dam slopes are flattened wherever required for stability or erosion protection reasons. The profile of pond areas is regraded so as to allow for natural surface run-off. Given that thick fine-grained tailings sludges in particular will drain very slowly over extended periods under the superimposed load, deep-reaching vertical wick drains are driven at depths of up to 30 metres into the tailings in order to enhance drainage and settlement.

In the last step, the contoured surfaces are covered with a **final layer** measuring 1.5 to 3.8 metres thick. Its primary goal is to reduce the infiltration of precipitation into the tailings in order to minimise the generation of contaminant-bearing seepage. The dimensioning of the final covers for the tailings management facilities is determined based on the potential environmental impacts (see Fig. 5). Landscape planning provides for afforestation of subareas as well as for the creation of open grassland areas. Concept for the handling of industrial buildings and facilities.

Figure 5: Standard profile of a contoured tailings management facility with the final cover in place



Concept for the handling of industrial buildings and facilities

After the termination of uranium production, there was no further use for most industrial buildings and facilities. Only a few units were used and remain in use for ongoing remediation work. The concept for dismantling and demolition stipulates that radioactively or chemically contaminated scrap and demolition rubble is to be disposed of within tailings management facilities and waste rock piles. Uncontaminated and decontaminated scrap is returned to the economic cycle. By contrast, uncontaminated demolition rubble is used for road construction on reclaimed Wismut areas.

Concept for the reuse of rehabilitated areas

Areas which have been contaminated or otherwise affected by mining activities and which are the responsibility of Wismut have to be prepared for reuse in compliance with the Federal Mining Act. However, this does not necessarily imply that proper shaping of the ground surface would restore pre-mining conditions. When developing concepts for the reuse of individual areas, Wismut is guided by existing regional land development and zoning plans.

The actual need for remediation of an area is determined based on the degree of established contamination and the nature of the envisaged reuse. The concept for the remediation of waste rock pile footprints, plant areas, roadways and railbeds essentially stipulates that all ground contamination be removed.

The release of areas for industrial, commercial, agricultural or forestry reuse is primarily subject to compliance with mining and radiation protection legislation. In accordance with regional land development and zoning plans, forests or grassland areas are the preferred forms of reuse for the vast majority of areas rehabilitated by Wismut. A small number of remediated plant areas are eligible for commercial or industrial reuse.

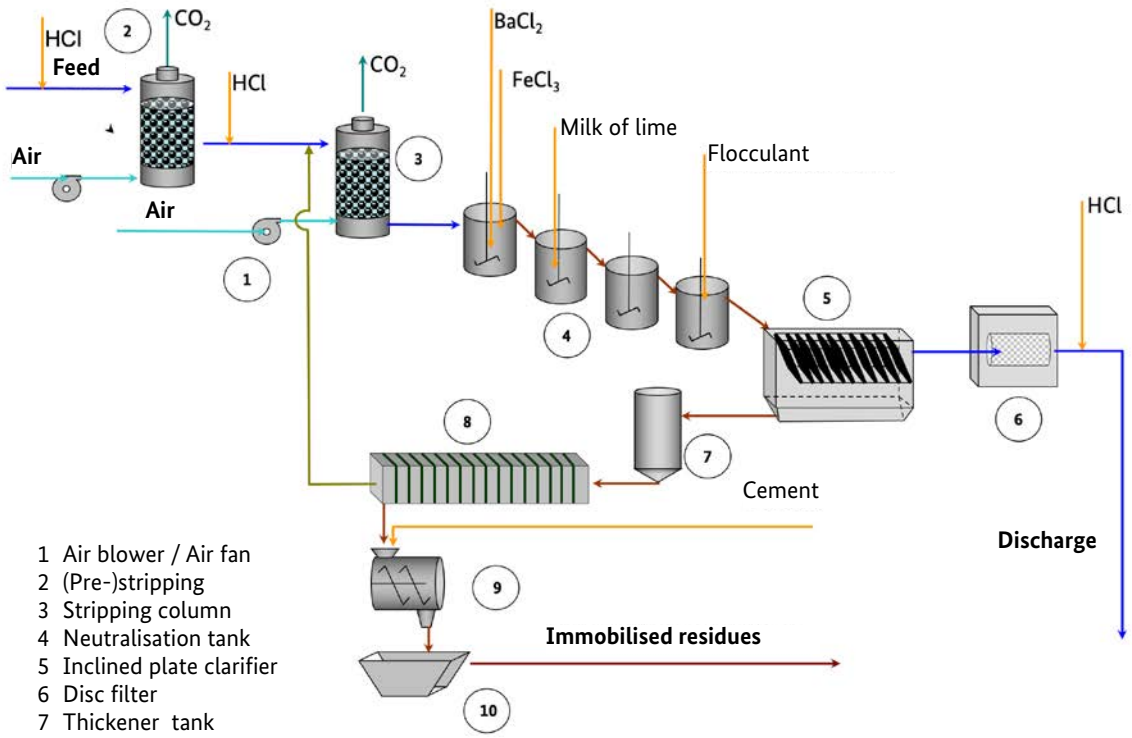
The demolition of old facilities (Königstein, 2014) and the remediation of the land enable reuse (Hammerberg waste rock pile, Bad Schlema 2020)

Concept for the handling of contaminated waters

Radioactively and chemically contaminated waters have to be treated in water treatment plants before being eligible for discharge into waterbodies (otherwise known as receiving waters). Both during controlled mine flooding and after its completion, flood waters that may be contaminated with uranium, radium, heavy metals and arsenic are released. The same is true of supernatant and pore waters, which have to be removed by pumping for tailings dewatering purposes, and also of seepage from covered tailings management facilities and waste rock piles. Wismut operates six water treat ment plants. Four of them use a flowsheet based on the lime precipitation process (see Fig. 6). By adding milk of lime, barium chloride and iron chloride, the heavy metals uranium, radium and arsenic are removed from the feed water as a low solubility precipitate. Water treatment residues are immobilised by the addition of lime and cement before their disposal in special cells.

Plate and frame filter press in a water treatment plant

Figure 6: Flowsheet for a water treatment plant using the lime precipitation process, as exemplified by the plant in Seelingstädt



Another process used in the new water treatment plant in Helmsdorf is based on the principle of ion exchange. In this case, water pollutants are removed using particular ion-exchange resins. The pollutant absorbed by the resin can be removed from it and safely stored in specially designated cells. The resin is regenerated, enabling it to be reused several times.

Implementation and approval of remediation concepts

Comprehensive planning work is required to translate remediation concepts into actual remedial action. In many cases, this is based on detailed **engineering services** covering a wide range of engineering and natural sciences. These fields include mining, geotechnics, mine surveying, civil engineering, geology, hydrology, chemistry, process engineering, plant construction, electrical engineering, measurement and control systems engineering, energy supply, logistics, forestry and landscaping, as well as radiological protection

(radioecology), which occupies a position of special importance. Mathematical modelling is used to assess the impact of various remedial options on water, air and soil quality as well as the radiation exposure of the population.

Initially, these engineering services serve to:

- Develop various remedial options,
- Perform technical feasibility studies, and
- Examine the efficiency and sustainability of the proposed remedial options.

When choosing the preferred option, the following requirements must also be taken into account:

- Safe working conditions and protection of the public during the execution of the required remedial operations,
- Total remediation expenditure including follow-up long-term care and maintenance tasks, and
- Public acceptance.

Moreover, engineering services serve as a basis for optimising work processes and quality control. Engineering services not available at Wismut are contracted out to specialised companies.

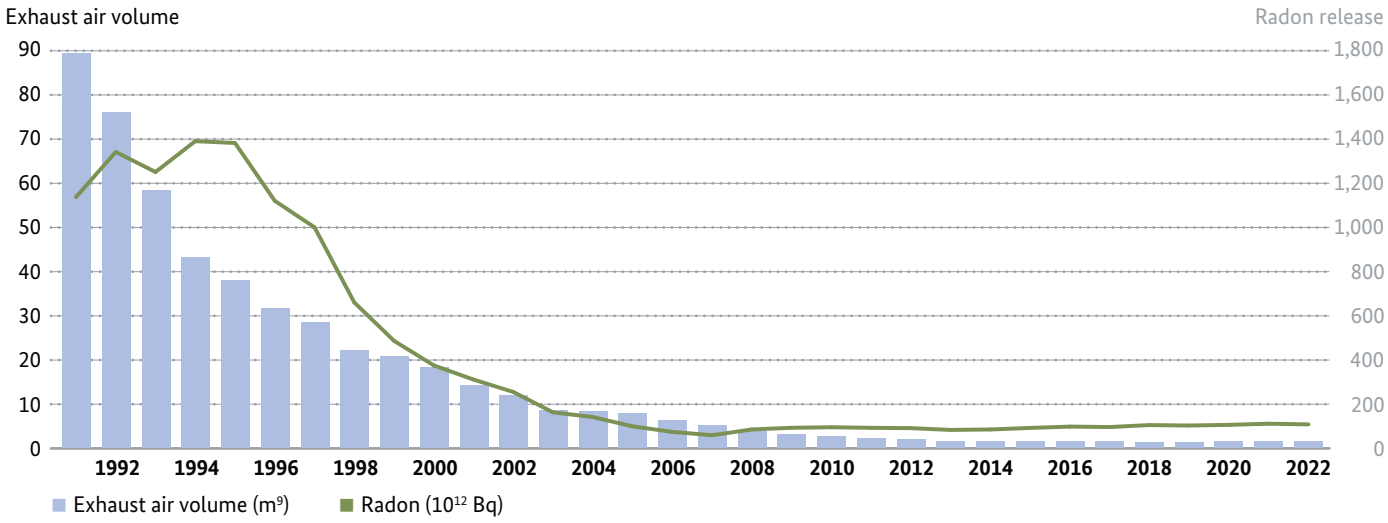
Briefing the **regulatory authorities** early on in the engineering planning stage allows for an informed discussion of technical and legal matters with these regulatory bodies and their consultants in Saxony and Thuringia. This, in turn, speeds up the process.

Since 1990, Wismut has been granted more than 10,000 licences. Some 4,700 were granted in Saxony, approximately 5,200 in Thuringia, and around 140 licences were awarded for remedial operations across state borders. Roughly half of the licences were granted under the provisions of mining legislation, while licences awarded under the provisions of radiological protection and water legislation each accounted for around 1,300 approvals.

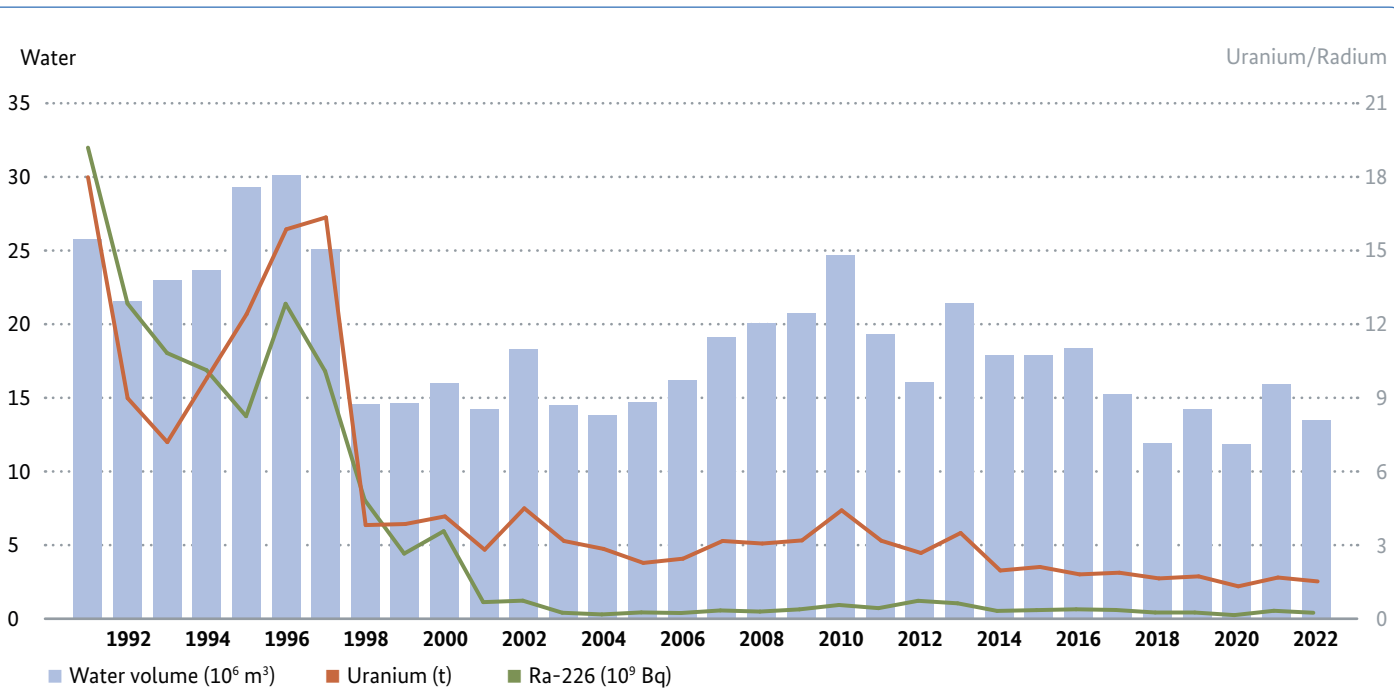
Coordination of remediation planning with the local municipalities is of particular importance. To this end, community representatives and Wismut GmbH meet at regular intervals. Wherever possible, reclamation at Wismut sites has to take local and district land-use planning into consideration.

Project support is provided by a consultant, who acts on behalf of the BMWK and is mandated to assess the planning and implementation of decommissioning and remediation measures for good practice and cost-efficiency. The Hanover-based Federal Institute for Geosciences and Natural Resources (BGR) has performed this task since 2012. The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMU) exercises federal supervision over licensing under radiological protection legislation by the Free States of Saxony and Thuringia. To this end, the BMU calls upon the expertise of consultants and the Federal Office for Radiation Protection (BfS).

Figure 7: Evolution of pollutant releases via the atmospheric and aquatic pathways for the entire Wismut area



Source: Wismut GmbH



Source: Wismut GmbH

3. Current status of the remediation work

Remediation is well advanced following 30 years of careful work (see Fig. 8) and has already been completed at four out of a total of seven sites. In Dresden-Gittersee and in Pöhla, remediation work ended in 2016 with the completion of the waste rock pile remediation. The completion of the works at the Lichtenberg open pit mine in 2018 officially marked the end of the remediation process at the Ronneburg site. At the Crossen site, substantial remediation work was completed in 2023 with the termination of the road construction, hydraulic engineering and landscaping work at the Helmsdorf tailings management facility. Work on remaining tasks, such as water management and environmental monitoring, will continue at all sites within the scope of Wismut's long-term tasks.

The other sites are in the final phase of substantial remediation. The largest remaining project is the remediation of the Culmitzsch tailings management facility. The planned completion of the work on this property is scheduled for 2028, with the exception of the still pending dismantling of technical infrastructure, will mark the end of remediation for Wismut. Over the next few years, Wismut's activities will increasingly shift towards long-term tasks, which will be the focus of the work for the coming decades, well beyond 2028.

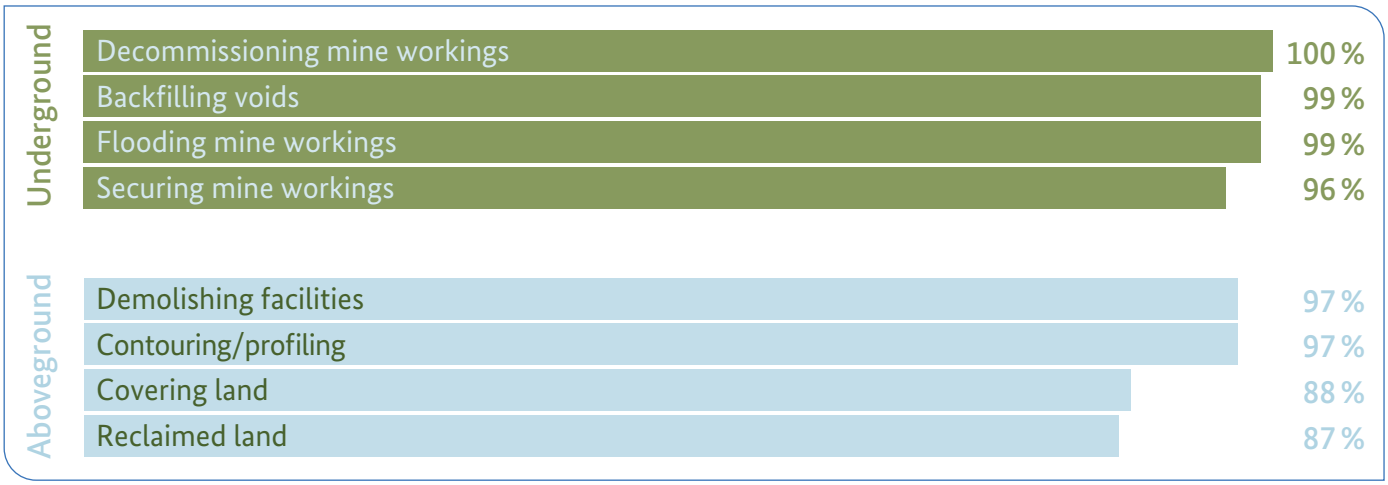
Mine remediation

The underground remediation work can be divided into two important processes, both of which go hand in hand: remediation of the mine workings and their subsequent flooding. Following approval by the regulatory bodies, Wismut implements the following general goals for underground remediation work:

- Removal of technical substances with the potential to pollute incoming groundwater, followed by mine flooding and the adjustment of mine ventilation to rising flood water levels,
- Remediation of surface openings,
- Securing surface stability by backfilling of near-surface mining voids, and
- Construction and operation of water treatment plants to reduce contaminant levels in flood waters prior to discharge into the receiving waters.

Flooding the numerous mines at the various Wismut sites represents a major challenge (for their locations see Fig. 1, p. 7). The aim is to flood most mines to the natural groundwater level, with the foremost requirement being to prevent surface subsidence and environmental degradation.

Figure 8: Current status of the remediation work, as at 2023



Bad Schlema – Hiking stop on the Hammerberg waste rock pile overlooking the spa park

Modelling of anticipated flood behaviour for the mining districts revealed very early on that groundwater resurgence would very probably result in the emergence of contaminated water. In preparation for such a scenario, Wismut installed deep wells, adit drainage and near-surface groundwater collection systems in the potential discharge areas. The intercepted mine or groundwater is collected and piped to the respective water treatment plant.

Almost all the mines have now been completely or largely flooded. Schlema is the only site where mining voids are to be kept open above the flooding level and maintained in the long term for ventilation purposes and to manage the radon levels in the local community. In Königstein, further measures to optimise long-term flood water management are to be implemented in the coming years.

Remediation of the mines at the Schlema-Alberoda site: From a subsidence area to a spa resort

Mining history at the Schlema-Alberoda site extends far back in time to the mid-15th century, when tin, iron, silver, bismuth, copper, cobalt and nickel were mined. Prospecting for uranium deposits in the region began in 1945. This subsequently led to the development of the smaller and less productive deposit in the Oberschlema area, where uranium was mined at a depth of 640 metres. However, mining activities were halted at the end of the 1950s due to the exhaustion of resources. There was no systematic mining remediation. Intensive mining activity resulted in mining-induced surface sinkholes and numerous incidents of land subsidence.

Uranium mining operations eventually shifted to Niederschlema-Alberoda, the lower Schlema valley and the banks of the Zwickauer Mulde River, which was home to one of the world's largest hydrothermal uranium ore deposits. Mining in the area reached depths of up to 1,800 metres below the level of the Markus-Semmler-Stolln gallery, which serves as Wismut's zero-metre level for surveying purposes. The veins of both deposits yielded approximately 80,500 tonnes of uranium.

Mining operations ultimately extended over an area of approximately 22 square kilometres and created underground mine openings on 62 levels with a total mined volume of around 41 million cubic metres; these workings were developed by means of more than 62 shafts and ventilation raises, numerous blind shafts, and several adits. Of that total, ten shafts, including four ventilation

Remediation of shaft 208, 2023

Underground remediation work in the Schlema-Alberoda mining field (2003)

shafts, as well as ten blind shafts, were still in operation after the cessation of mining activity. Horizontal mine voids totalled 4,200 kilometres. When remediation work started, 176 kilometres of mine voids on seven levels were still in use.

Flooding of the mine began as early as 1991, when the mine water pumping system was shut off, and is now almost complete. Surveying and geomechanical monitoring shows that some flooding-induced ground movements are still occurring; however, they are negligible in comparison to the mining-induced movements. The residual void of around 0.5 million cubic metres remaining below the Markus Semmler level is used as a buffer storage facility to compensate for peak inflow levels or temporary shutdown of the water treatment plant. The plant, which was built at a cost of approximately 15 million euros in 1998, had treated some 137 million cubic metres of contaminated flood water by the end of 2022.

By the end of 2022, 55 shafts had been remediated. In order to protect the ground surface against subsidence, 210,000 cubic metres of near-surface mine voids have been backfilled in the Schlema-Alberoda area. A major focus of the remediation work was the securing and backfilling in the large subsidence area in Oberschlema, which has now been turned into a spa park. Another important task was the establishment of stable and long-lasting mine ventilation on the Markus Semmler level. For this purpose, ventilation shaft 382 was equipped with new mine fans.

Underground remediation work still to be accomplished will focus on the Markus Semmler level in the Oberschlema mining field, where further reopening and reconstruction of the drifts is required to complete the establishment of stable and long-lasting mine ventilation.

Flooding and remediation of the Königstein mine

Prospecting for uranium in the Upper Cretaceous sandstones of the Elbe rift valley south-east of Dresden began in the early 1960s. This led to the discovery of the Königstein deposit in 1963. Mine development commenced as early as 1964 and eventually comprised five pit shafts and seven ventilation holes as well as headings, extraction drifts and cross-cuts on four levels. The surface area affected by mining operations extends over approximately six square kilometres near the localities of Königstein, Bielatal, Langenhennersdorf and Struppen. Systematic uranium ore mining operations commenced in 1967 using conventional underground mining methods.

Following the development of an in situ leaching process, the mine shifted to full in situ leaching of uranium in 1984 in response to declining ore grades. Leaching of the ore was performed with

groundwater to which sulphuric acid had been added. This liquor leached the uranium from the underground rock, removing the need for rock extraction. By 1990, more than 55 million tons of sandstone had come into contact with the leach liquor. When mining ceased, a portion of the liquor remained locked in the sandstone as pore water.

When uranium production was terminated in 1990, the mine had produced some 18,000 tonnes of uranium. Of that total, around 70 per cent was produced from conventional mining and 30 per cent from in situ leaching. The mine flooding concept developed in 1991 for Königstein mine provides for monitored and controlled flooding involving the construction of control drifts and water treatment in an above-ground facility. Remedial operations accordingly focused on:

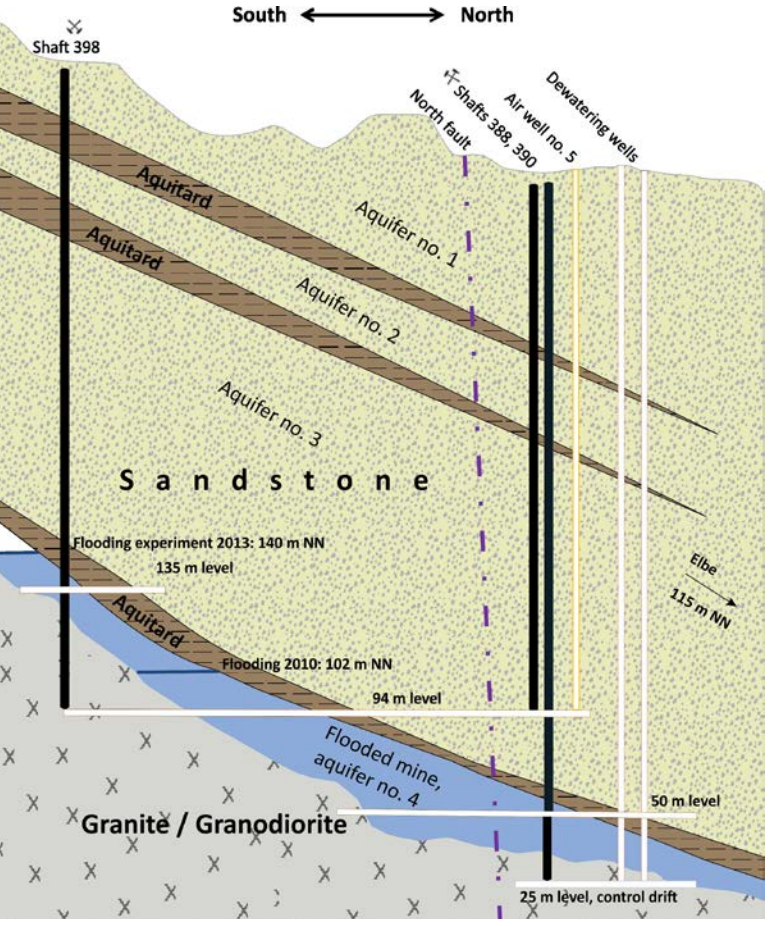
- Removal of substances with the potential to pollute the incoming groundwater (greases, oils, etc.),
- Construction and operation of control drifts aimed at preventing discharge of contaminated water and enabling direct monitoring and sampling of flood water,
- Attenuation of the sulphuric acid concentration of leach solutions by means of flood washing,
- Removal of easily soluble uranium and other heavy metals, and
- Sealing of the mine perforations between the third and fourth aquifers to minimise direct water rise into the third aquifer during flooding.

The construction of underground control drifts to intercept contaminated flood water was completed in 1994. Following experimental flooding conducted over several years, flooding of the Königstein mine was initiated in 2001. Since then, natural inflow and the controlled addition of clean groundwater have gradually raised the water level in the initially open control drifts. To control the rise, two approximately 300-metre-deep wells were drilled.

Drainage system for the remediation of the Königstein mine (2011)

While the underground mine was prepared for flooding, a water treatment unit was built to treat contaminated flood water. Since becoming operational in 2000 and following a technical modification between 2018 and 2020, the plant has treated around 70 million cubic metres of contaminated water. Concentration levels of trace elements and uranium in the flood water have significantly decreased as a result of the multi-year flushing of the sandstone in the underground mine. Immission measurements conducted in the Elbe River show that there is no environmentally relevant impact on the Elbe due to discharge of treated water from the Königstein site.

Figure 9: Schematic vertical profile of the Königstein mine, showing flood water level as at Dec. 2022 (not to scale)



The flood monitoring network monitors the rise of he groundwater level in the third and fourth aquifers, the void subject to flooding, and the groundwater quality during and after flooding of the Königstein mine. Monitoring focuses on areas constituting zones of potential flood water rise to the third aquifer and on areas downstream of the third and fourth aquifers along the northern and western edges of the mine.

With the plugging and sealing of shafts 388/390 at the end of 2012, mine closeout and hence mine remediation were completed. Since January 2013, flood water has been kept at a level of approximately 139.5 metres above sea level (see Fig. 9). A temporary increase in the flood water level to 150 metres above sea level as part of a hydraulic test in 2017 showed that no material reactions resulted in the adjacent aquifer. Wismut therefore intends to continue the gradual flooding of the mine by employing supporting measures to improve the condition of flood water. The goal is to achieve stable hydraulic and hydrochemical conditions in order to complete remediation at the site. From 2024, a second test will be supported with an injection procedure that serves to accelerate the improvement of acidic mine water.

Waste rock pile remediation

Waste rock piles marked the landscape in Saxony and Thuringia during the time of Wismut's active mining operations. Remediation of the waste rock piles is now well advanced at all sites. The renaturing or relocation of these objects provides an impressive demonstration of the progress Wismut has achieved in its remediation work. The status of the remedial operations and the basic procedure followed are summarised in Table 1 and explained below by way of example.

Table 1: Dimensions of selected waste rock piles and current status of their remediation

Location	Waste rock pile name/ complex	Total volume (million m³)[3]	Remediation process	Remediation time frame
Ronneburg, 14 waste rock piles		**141**		
Including	Absetzerhalde	70.1	Relocated into open pit mine	1993 – 2006
	Nordhalde	31.3	Relocated into open pit mine	1998 – 2003
	Beerwalde (incl. the relocated Drosen and Korbußen waste rock piles)	9.6	In situ	1991 – 2003
Schlema, 21 waste rock piles		**42**		
Including	Shaft 371 waste rock piles	13.7	In situ	1993 – 2025*
	Shaft 366 waste rock pile	7.4	In situ	1997 – 2008
	Shaft 38 new/ 208 waste rock pile	3.8	In situ	1999 – 2007
Seelingstädt, 4 waste rock piles		**55**		
Including	Lokhalde	16	Relocation to Culmitzsch tailings management facility in progress	1990 – 2028**
	Waldhalde	21	Partial relocation to Culmitzsch tailings management facility in progress	2008 – 2023
	Südwesthalde	14	Partial relocation to Culmitzsch tailings management facility in progress	2023 – 2025
Pöhla, 4 waste rock piles		**2**		
Including	Luchsbachhalde	1.9	In situ	1993 – 2008
Königstein, 1 waste rock pile				
	Schüsselgrund waste rock pile	4.4	In situ	1991 – 2025*
Dresden-Gittersee, 2 waste rock piles		**1.4**		
Including	Gittersee waste rock pile	1.1	In situ	1991 – 2006
Crossen, 1 waste rock pile				
	Bergehalde Crossen waste rock pile	**3.2**	Relocated to Helmsdorf tailings management facility	1996 – 2018

*excluding operation of the waste disposal facility
**excluding demolition of infrastructure measure

Worked-out Lichtenberg open pit, Ronneburg site (1992)

Schmirchauer Höhe (Schmirchau Heights), Ronneburg site (2021)

Waste rock pile relocation into the Lichtenberg open pit mine at the Ronneburg site

One of the most impressive measures is the site remediation in Ronneburg, where almost all the waste rock piles in the district south of the A4 motorway have been relocated into the remaining open mine pit in Lichtenberg.

Relocation of the overburden material into the former open pit mine resolved several problems simultaneously. On the one hand, the remaining open mine pit was backfilled, and thus remedies the lack of long-term stability of the slopes. On the other hand, waste rock piles in need of remediation existed in various locations. To avoid the need to intercept and treat acid seepage from several waste rock piles for decades to come, this waste rock has been concentrated in a single location. Placing waste rock with elevated acid generation potential at the bottom of the open pit mine has met this requirement in an ideal manner, since the backfilled material will for the most part be submerged below the groundwater table once flooding is com pleted. Groundwater provides efficient protection against air access and thus against acidification.

However, the available pit volume of 84 million cubic metres was too small to accommodate the total volume of 133 million cubic metres made up of relocated waste rock, excavated contaminated soil and rubble from the demolition of buildings and structures. The surplus material was therefore used to build a mound as a landscape feature on top of the backfilled open pit. In commemoration of the Schmirchau community, which had to make way for the development of the open pit mine, the mound is called the Schmirchauer Höhe (Schmirchau Heights). This landscape feature and the reclaimed Nordhalde footprint in the Gessen valley were presented as the “New Ronneburg Landscape” at the 2007 National Horticultural Exhibition.

The Lichtenberg landfill was provided with a 1.6-metre-thick final cover, which was completed in June 2018. Forests are the primary intended

Final cover for waste rock pile 371/II at the Aue site (2015)

reuse option for the landscape feature covering a total of 222 hectares. A network of logging roads and hiking trails totalling 20 kilometres has been established for forest management and tourism development around the Schmirchauer Höhe.

The footprints of all the relocated waste rock piles have been decontaminated and remediated. Access paths and, where necessary, drainage ditches have been created on the waste rock pile footprints. Forms of reuse realised at the Ronneburg site to date include forest, open land, specially designed biotopes, commercial space, a flood retention basin and solar parks (photovoltaics).

The strategy adopted in the Ronneburg district, where the Drosen and Korbußen waste rock piles have been relocated to the Beerwalde pile, follows a similar rationale to the **waste rock pile relocation** into the worked-out Lichtenberg open pit, namely to concentrate the overburden material of the three piles located north of the A4 motorway in a single location. This solution was more cost-effective than remediating all three piles individually in situ. Excavating and moving the waste rock piles at the Ronneburg site involved the use of off-highway equipment. At the peak level of activity, a fleet worth some 45 million euros of up to 75 massive earthmoving machines, including dumper trucks, excavators, wheel loaders and crawler dozers, excavated and moved up to 40,000 cubic metres of overburden material a day.

Remediation of the waste rock piles at the Aue/Schlema site

During the course of mining operations, an extensive landscape of waste rock piles emerged at the site of the historical Oberschlema radon spa. In addition to the waste rock dumped right in the town's centre, a number of conical waste rock piles disturbed the local scenery. Mining operations also extended into the Silberbach valley and onto the summit of the Hammerberg. In an effort to redress the lack of dumping grounds available in the vicinity of the town, a rail track was built to haul waste

rock for dumping along the slopes of the sur rounding hills. Waste rock dumping was extended to the Borbach valley within the boundaries of the municipality of Wildbach. Mining waste was dumped on 42 waste rock piles with a footprint covering an area of 311 hectares. Wismut is responsible for the reclamation of 21 of these waste rock piles, which contain a total of approximately 42 million cubic metres.

Green slopes and completely recultivated waste rock pile landscapes now characterise the area from Oberschlema to Alberoda. The focus of waste rock pile remediation during forthcoming years will be on waste rock complex 371, where the deposition of contaminated soil and rubble from land remediation and the demolition of buildings, as well as the deposition of immobilised water treatment residues, will continue. Waste rock pile covering will be completed by 2025 with the exception of the engineered area, where immobilised residues are to be deposited. Long-term care and maintenance are planned for the reclaimed areas in order to ensure the long-term success of the remediation work. In the vicinity of the waste rock piles, remedial progress is clearly reflected in the diminished radon concentrations in the ambient air. Many sites have reached compliance with radiation pro tection standards. At some locations, work is continuing to further improve the situation.

Waste rock pile landscape at Bad Schlema (2021)

Remediation of tailings management facilities

The remediation of the tailings management facilities presented major challenges for Wismut. Despite this, the undertaking has been turned into a success story. The expertise gained in the remediation of tailings management facilities of this magnitude (see Table 2) has made Wismut a nationally and internationally respected point of contact for the remediation of similar mining legacies.

Based on a large number of scientific and technical studies and pilot-scale tests, dry remediation in situ was selected as the preferred option. This process consists of the following key steps:

- Interim covering of sandy tailings surfaces to prevent windblown dust,
- Removal of supernatant water, followed by
- Interim covering of low load-bearing surfaces to produce a load-bearing working platform,
- Contouring of the dams to ensure long-term stability,

Top: Interim cover on the Culmitzsch tailings management facility (2014)
Bottom: Water collection system at the Culmitzsch tailings management facility (2022)

- Contouring of the compressible (soft) fine tailings in conjunction with measures to accelerate settlement where necessary to create a stable surface contour for surface drainage,
- Final covering of the tailings and sowing of primary vegetation for erosion protection,
- Landscaping of the surface in compliance with the requirements stipulated in the approval, usually as forest or open land,
- Parallel collection and treatment of contaminated waters.

Table 2: Parameters of the tailings management facilities

		Culmitzsch	Trünzig	Helmsdorf/Dänkritz I	Total
Area	ha	299	144	241	**684**
Tailings volume	million m^3	85	19	50	**154**
Max. tailings thickness	m	72	30	55	

Construction of the interim cover at the Culmitzsch tailings management facility (2016)

The Culmitzsch and Trünzig tailings management facilities at the Seelingstädt site

At the end of 1990, the Seelingstädt site comprised the Seelingstädt mill as well as two tailings management facilities: Culmitzsch and Trünzig. Commissioned in 1960, the Seelingstädt mill was Wismut's largest and most advanced processing facility. It processed 110 million tons of ore, coming for the most part from Ronneburg. The site of the mill was chosen for its proximity to the two worked-out open pit uranium mines of Culmitzsch and Trünzig, which could be used as washing ponds to accommodate the processing residues.

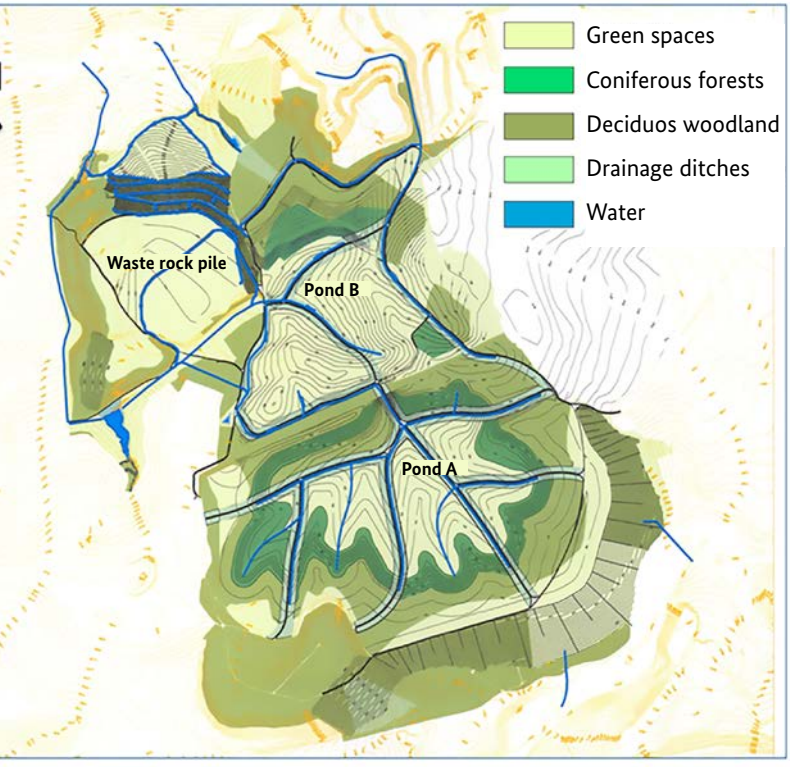
The ore processing residues were discharged into the Trünzig tailings management facility from 1960 to 1967, and then into the Culmitzsch tailings management facility from 1967 until 1991. Due to the process technology, each facility was divided by a dyke into two ponds to provide separate storage of residues from the acid and alkaline leaching process respectively. The Trünzig and Culmitzsch tailings management facilities covered a total surface area of about 450 hectares and contain some 104 million cubic metres of tailings (Table 2, p. 29). In 1990, the volume of supernatant water in the ponds amounted to some 2.4 million cubic metres.

Initial remediation work at the Culmitzsch and Trünzig tailings management facilities began as early as 1990 and 1991, respectively, when interim covers were placed on exposed tailings beaches in order to eliminate immediate risks and reduce local radiation exposure arising from the dispersal of windblown dust. In the following period, super-natant water was pumped out, and the areas exposed due to the falling water level were then gradually covered with an interim cover. Building the interim cover for the Trünzig tailings management facility consumed some 1.1 million cubic metres of earthen material, for the most part excavated during the renaturation of the Finkenbach valley, which was used as a dumping ground for overburden material while the facilities were in operation. Some 3.7 million cubic metres of sand, gravel, and material excavated from the Lokhalde waste rock pile were needed to complete the interim cover on the larger Culmitzsch tailings management facility. Placement of the interim cover on pond B was completed in 2006, and on pond A in 2017.

Recontouring of the dam and pond sections at the Trünzig tailings management facility started in 2000. The gently undulated area was designed so as to allow surface run-off from pond A to discharge towards the Culmitzsch lowland, while run-off from pond B discharges towards the Finken-bach valley. Contouring and final cover building at the Trünzig tailings management facility required some 6.5 million cubic metres of overburden material. In 2013, the final cover was placed across the entire facility, and the remediation of the tailings management facility was largely completed. Only the connection of the southern pond B to the Finkenbach receiving stream is still pending.

Culmitzsch tailings management facility with the Trünzig tailings management facility visible in the background (1995)

Figure 10: Reuse concept for the Culmitzsch tailings management facility



Contouring work on the Culmitzsch tailings management facility commenced in 2007 with the flattening of the Norddamm for stability reasons. This work is complete. Contouring work is under way on ponds A and B. The contouring of pond B is complete apart from a small remaining area, and the final cover is already in place across considerable parts of the pond. Contouring work is currently focused on pond A. Contouring and final cover placement for the entire tailings management facility is scheduled for completion by 2028. To date, this work has consumed 20.9 million cubic metres of material. Some eleven million cubic metres of additional contouring and covering material will be required to complete the remediation of the Culmitzsch tailings management facility.

Ultimately, the pond section of the Culmitzsch tailings management facility is to be reshaped into a gently undulating landscape that discharges its run-off primarily towards the north. The reclaimed former pond areas are to be largely afforested with coniferous and deciduous trees to form mixed woodland. Grassland (open land) is the main reuse option envisaged for the remaining areas (see Fig. 10).

Helmsdorf and Dänkritz I tailings management facilities at the Crossen site

In contrast to the Culmitzsch tailings management facilities, the Helmsdorf and Dänkritz I tailings management facilities at the Crossen site have already been almost completely remediated. The approach here was similar to that adopted with the tailings management facilities in Seelingstädt, namely beginning immediately after the cessation of production by placing interim covers on the sandy tailings on the exposed tailings beaches to prevent windblown dust. In addition, seepage collection systems were extended. The actual remediation work began in 1996, after the commissioning of the new water treatment plant at the Helmsdorf site, where supernatant water of the tailings pond could be treated. This allowed the water level in the Helmsdorf tailings facility to be gradually lowered.

During the following years, the exposed tailings areas were covered with an interim layer. By 2011, some 200 hectares had been covered with a 1.5-metre interim layer, which consumed 2.9 million cubic metres of waste rock, sand and gravel. Reducing the slope angle and partial excavation of the embankment dams at the Helmsdorf tailings management facility began in 2002 with a view to cre ating a final contour designed as an undulating landscape of hills and valleys. Since 2005, the contoured areas are in the process of being covered with a final layer of 1.5 metres of mineral soil. The plateau relief is designed to allow discharge of surface run-off towards the Wüster Grund creek and Oberrothenbach creek. A small portion of the run-off will discharge towards the Zinnbach creek, just like the run-off from the Dänkritz I tailings management facility, where contouring and cover placement were completed in 2007.

Helmsdorf and Dänkritz I tailings management facilities (2022)

Main dam at the Helmsdorf tailings management facility (2013)

Contouring and final cover placement at the Helmsdorf and Dänkritz I sites were completed in 2023. Some twelve million cubic metres of material was used for this purpose. The reclaimed facility will require maintenance and monitoring work for many years to come.

Construction of channels in the main dam (2011)

Dismantling and demolition of structures and facilities and subsequent land remediation

Around 99 per cent of the industrial plant and buildings earmarked for demolition have already been dismantled. The priorities for the remaining work will be the plant premises in Königstein, the Lichtenberg unit at the Ronneburg site, and land remediation at shaft 371 in Aue. In the course of the demolition of the plant structures and buildings, radioactively or chemically contaminated construction waste was relocated to the tailings management facilities and waste rock piles, where it was used for the contouring and covering systems. Uncontaminated demolition material is mostly used for roadwork on Wismut sites. Scrap from buildings and facilities that were not subject to the handling of radioactive materials, e.g. the sulphuric acid plant and the industrial power plant at the Seelingstädt site, can be directly recycled following the issuing of a corresponding certificate.

Steel scrap from radiation protection areas, on the other hand, is tested for total surface radioactivity using a procedure specifically designed for Wismut applications. If surface activity levels are below the release threshold, the scrap is released for smelting. It was possible to recycle large quantities of contaminated steel scrap after decontamination by sandblasting and thus return the material to the economic cycle. Decontamination residues and unusable contaminated scrap were disposed of in engineered cells at the tailings management facilities and sealed with concrete.

Where the building fabric permitted it, some buildings were preserved (e.g. the laboratory building in Seelingstädt) and repurposed for remedial operations. Plans for former mining areas envisage remediation for agriculture and forestry purposes and industrial and commercial reuse. In addition,

Site of the former Crossen processing unit and the Bergehalde waste rock pile (2021)

grassland, alluvial landscapes and flood retention areas are being created, such as on the premises of the ormer Crossen processing unit.

Further examples of potential forms of reuse include the solar parks on the premises of the former Schmirchau mining unit and on the footprint of the former Reust waste rock pile at the Ronneburg site. Art and culture have also found a place on the newly created areas. Under the banner of "Resurrektion Aurora", an open-air museum presenting the history of uranium mining by Wismut and a sculpture park were inaugurated on the premises of the former Drosen mining unit as part of the 2007 National Horticultural Exhibition. The Marienschacht pit at the Dresden-Gittersee site and its Malakoff tower form an industrial monument. Together with its associated waste rock pile, it constitutes a mining heritage ensemble.

One important goal for the demolition of the industrial facilities and structures and for land remediation is the gradual withdrawal from sometimes extensive areas, accompanied by the concentration of the company's activities in a small number of central administrative and functional buildings. The Ronneburg site is a good example of. In 1992 mining sites covering a total area of ca. 1,520 ha were owned by Wismut GmbH including areas of waste rock dumps, industrial sites and traffic areas, ca. 1100 ha had to be remediated, because they were both radioactively contaminated and contaminated by heavy metals or by organic components. To date only a few buildings of the former Lichtenberg mining unit are still used.

Malakoff tower of the Marienschacht pit near Dresden (2017)

Sculptures under head frame 403 of the former Drosen mining unit (2020)

4. Long-term tasks

Taking measurements for the release of remediated land (2020)

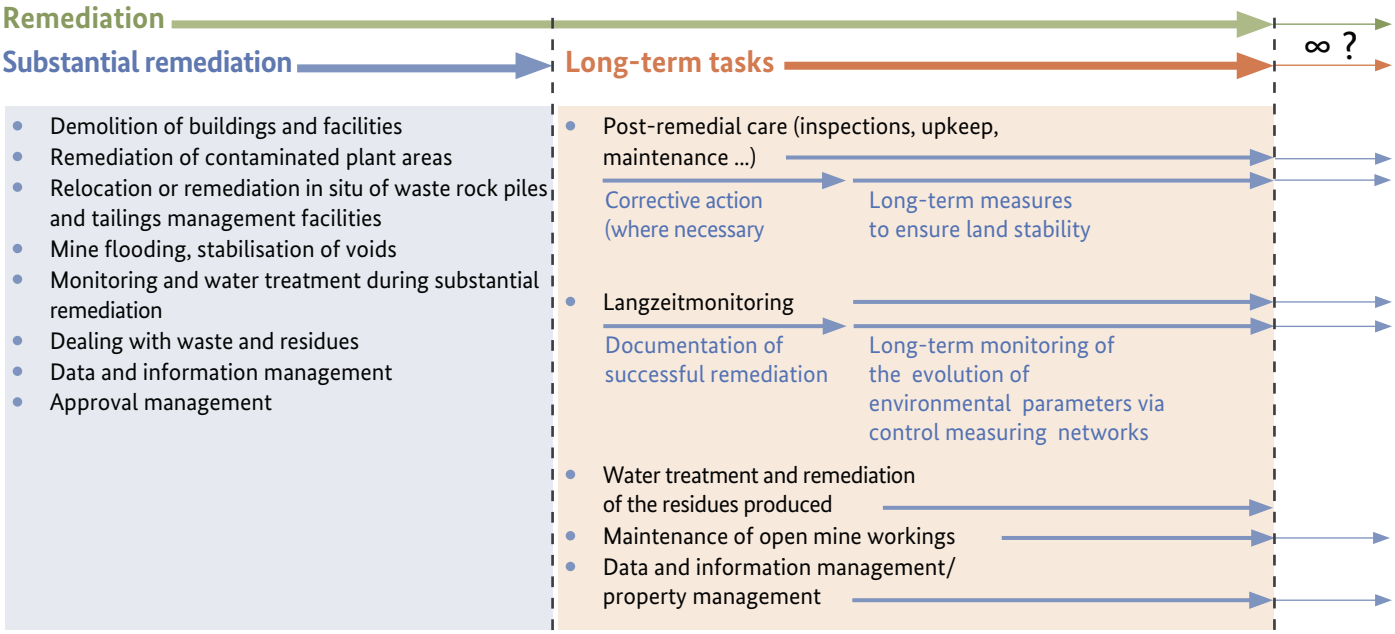
Once remediation is complete, Wismut will remain responsible for the long-term tasks (see Fig. 11). These are also part of the remediation. Substantial remediation work has already been completed at the Dresden-Gittersee, Pöhla, Ronneburg and Crossen sites. Substantial remediation of the last object at the Seelingstädt site will be completed in 2028. The whole company will then transition into the phase of long-term tasks. Wismut's remediation programme considers long-term tasks over a 30-year period and divides these tasks into:

- Securing and maintaining open mine workings
- Intercepting and treating water
- Long-term monitoring
- Monitoring, care and maintenance of land, properties and facilities
- Information and knowledge management

The long-term tasks to be accomplished vary depending on the site. Post-remedial care measures for the areas of remediated waste rock piles and tailings management facilities, as well as the access paths and water drainage systems constructed on them, are designed to maintain the state achieved in the long term. They are to be carrried out at specified intervals or after special events, such as storms. Post-remedial care measures include tending to vegetation and clearing ditches constructed for water drainage. Reclaimed plant areas often do not fall under post-remedial care: they are usually sold or remain in use by Wismut.

Immediately after substantial remediation work is completed, measurements of environmental parameters are taken to verify whether the planned remediation goal has been achieved. If necessary, corrections are made. Subsequently, the evolution of specific environmental parameters on the remediated properties is observed within the scope of long-term monitoring. A measurement network tracks system behaviour over a long period of time.

Figure 11: Schedule of remediation activities



Helmsdorf water treatment plant (2022)

One long-term task required at almost all Wismut sites is the interception and treatment of contaminated water, which also encompasses the remediation of the residues from the water treatment. Maintaining open mine workings, the mine ventilation systems and underground water drainage constitutes another long-term task. In addition, information and knowledge management, including property management, is becoming an increasingly important task.

Securing and maintaining open mine workings

Regular inspections and securing work are required for the parts of the mine workings that cannot be flooded. Maintaining water drainage systems and ventilation systems and precluding potential subsidence damage are of particular importance here. Ground movements induced by extraction and flooding must be monitored until they have completely subsided.

Intercepting and treating contaminated waters

Water treatment plays a key role during active remediation and is one of the most important activities that will continue beyond the end of remediation. It accounts for the largest share of the costs of long-term tasks at around two-thirds. The aim is to intercept all contaminated waters, to treat them to achieve compliance with authorised discharge limits and to subsequently discharge them into the receiving waters.

Contaminated waters occur as seepage in the vicinity of tailings management facilities and waste rock piles, as supernatant water and as flood water. The pollutant concentrations and the amount of water produced will gradually decrease as remediation progresses. For example, the amount of seepage from the tailings management facilities will decline over time as a result of the covering systems. However, the seepage flow will never dry up completely. In addition, seepage quality will not comply with the standards for direct discharge into the receiving waters for a very long time, as the hydrochemical self-cleansing processes proceed slowly. It must therefore be assumed that the water treatment plants will continue to operate for an extended period of time. In the vicinity of the

Sedimentation tank at the Schlema-Alberoda water treatment plant (2021)

Trünzig, Culmitzsch and Helmsdorf/Dänkritz tailings management facilities, contaminated seepage is intercepted in rows of wells and deep drains, and then treated in the Seelingstädt or Helmsdorf water treatment plants. The treated waters are discharged into the catchment area of the river White Elster or the river Zwickauer Mulde.

Water management at the Königstein, Aue/Schlema, Ronneburg and Pöhla mining sites is also based on an extensive water collection and treatment system. An integral component of this work is the is the metrological monitoring of the water disharge. As pollutant concentrations fall, a decision as to how to optimise mine water interception and discharge will be reached in due course.

Water treatment does not form part of the long-term tasks at all sites. A specific feature of the Dresden-Gittersee site is that the mine waters do not require treatment prior to their discharge into the Elbe due to low pollutant concentrations. Waters from the flooded Dresden-Gittersee mine are drained via the newly constructed WISMUT gallery into the Tiefer Elbstolln adit and then subsequently into the Elbe. Following the completion of the gallery, it was therefore possible to dismantle the water treatment plant in 2015. As a consequence, construction of the WISMUT gallery not only mitigates environmental impacts but also has costsaving benefits.

The water solution developed for the Dresden-Gittersee site, consisting of the WISMUT gallery and Tiefer Elbstolln adit (2016)

Sampling at groundwater measuring stations at the Königstein site (2017)

Sample analysis in the Seelingstädt laboratory (2019)

Environmental monitoring

Impacts and results of remediation activities are registered by a comprehensive monitoring system. In 2022, Wismut operated some 1,000 groundwater measuring stations and almost 400 surface water measuring stations, which monitor the contamination of groundwater and the receiving waters with radionuclides, heavy metals and other pollutants. Furthermore, measurements of radionuclides and environmental pollution are taken at some 400 atmospheric monitoring stations, in addition to soil and biomass sampling. Measuring networks designed to detect movements of the ground surface, which may be caused by the deformation of underground voids and mine flooding, complete the series of monitoring measures. Based on monitoring results, changes in environmental impacts are recorded. The data acquired is stored in databases and shared with regulatory bodies and the public in the form of reports. Reporting serves to demonstrate compliance with legal and regulatory standards and allows the success of remediation activities to be assessed. As remediation work progresses and remediated objects proceed into long-term tasks, the number of measuring stations required will decrease.

Landscape maintenance at the Pöhla site (2014)

Care and maintenance

Care and maintenance serves to ensure the long-term success of the remediation activities in the areas of forest and grassland established on the covered tailings management facilities and former waste rock piles, as well as on the renatured plant premises and dump footprints. This work focuses on grass mowing and grazing, clearing ditches and channels, and forest tending.

The example of the Lichtenberg open pit mine will be used below to describe the requirements for the maintenance of the new landscape feature in more detail. The 222-hectare fill body has been covered, sown with protective seeding and partially afforested. It is subdivided into a mosaic of planting, sown and ecological succession areas. The individual areas are developing into a network of biotopes that is connected to the surrounding countryside via access paths and across boundaries between different types of use. A variety of tree groups at entry points and intersections of access paths supplement the plantings. Woodland areas have been afforested or sown with native wood species, such as oak, maple, lime and larch of suitable origins.

Forest is the intended type of reuse for 70 per cent of the surface of the covered object and serves as an integral part of the covering concept. Finally, the integration of the feature into the landscape is an important consideration. The plans for the establishment of the new forest took into account the creation of open lines of sight and attractive viewing points, such as the Schmirchauer Höhe (Schmirchau Heights). The newly formed habitat can be accessed via an extensive network of paths, which is primarily used to maintain, care for and monitor the landfill and its cover. The landfill is becoming an attractive feature of the landscape, which will gradually integrate into the surrounding countryside as the areas of forest and open land evolve.

In the years ahead and with the completion of the remediation activities, the effort invested in care and maintenance will increase at all Wismut sites. Currently, some 500 hectares are to be managed in this way. Once substantial remediation has been completed, this figure will rise to 1,267 hectares.

Information and knowledge management

Documenting the remedial operations and knowledge management constitute a long-term task of enormous importance. The goal is to ensure the long-term availability of information on remediated properties and remediation technologies as well as technical data. One key activity is preparing the documentation of the remediation work, which proceeds in parallel with the digitalisation and integration of relevant documents into Wismut's information systems. The existing information network is being adapted to the requirements of the upcoming long-term tasks by expanding the geographically based and intuitive search functions. The aim is to ensure both internal knowledge management and the preservation of knowledge for future generations.

Clearing the water channel of the fill body at the former Lichtenberg open pit mine (2016)

5. Abandoned Wismut sites

In the early 1960s, areas and facilities previously used for uranium mining operations but no longer required by the predecessor SDAG Wismut were returned to the local authorities or private owners, for the most part in an unremediated state. For these sites, which are known as abandoned Wismut sites, Wismut GmbH has no remediation obligations under the provisions of the Wismut Act, as these sites were neither the property of Wismut GmbH on 30 June 1990 nor ceded to the company for unlimited and unrestricted use. A survey of these properties was drawn up with the legacy inventory compiled by the Federal Office for Radiation Protection on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

This legacy inventory served as the basis for an initial agreement concluded in 2001 between the Federal Government and the Free State of Saxony concerning seven priority remediation projects in Johanngeorgenstadt, Breitenbrunn and their environs. The Federal Government and the Free State of Saxony provided funding totalling approximately 4.8 million euros for these so-called “priority objects”.

As Wismut GmbH proceeded with its remediation work under its statutory mandate, the municipalities in the region faced mounting problems resulting from the abandoned sites. In September 2003, the Federal Government and the Free State of Saxony, without prejudice to their respective legal positions, signed an initial administrative agreement, expiring in 2012, concerning the remediation of abandoned Wismut sites in Saxony. A funding volume of 78 million euros was provided under the agreement, with the Federal Government and the Free State of Saxony each contributing 50 per cent. As with remediation under the provisions of the Wismut Act, the goal was – and is – to mitigate environmental damage and to restore an intact environment for the people in the affected former mining regions. At the same time, these activities are intended to lay a crucial foundation for positive regional development and economic revival in the municipalities.

Remediation work in Breitenbrunn in the Rabenberg mining district (2023)

Securing surface subsidence in Dörfler Weg, Annaberg-Buchholz

Inventories drawn up in 2012 and 2016 showed that the allocated budget and time frame were by no means sufficient to implement all the urgently needed remediation measures for the approximately 1,900 individual objects recorded in the inventories. Remediation project implementation proved to be much more complex than envisaged, legislative changes concerning nature conservation and environmental and radiation protection had to be taken into account, and previously unknown abandoned Wismut sites were added to the scope.

This led the Federal Government and the Free State of Saxony to sign supplementary administrative agreements in 2013 and 2019. Under these agreements, they provided an additional 138 million euros for remediation measures in 2013, followed by a further 229 million euros in 2019.

These funds are intended to provide a sound basis for the successful completion by 2035 of the remediation of the abandoned Wismut sites, which began in 2003 (total funding volume: approximately 445 million euros). Any costs arising after this point will be borne by Saxony alone.

The approval, steering and coordination of the remediation tasks is the responsibility of the remediation advisory board established for this purpose. Wismut GmbH is mandated to implement the projects. It has been commissioned as the project executing organisation by the Free State of Saxony. Among other things, Wismut GmbH is obliged to award a minimum of 50 per cent of the available funds to external companies as public contracts, with a view to providing positive impetus for regional development.

Remediation proceeds according to urgency on the basis of concepts for site remediation and clean-up that are agreed with the municipalities affected. In addition to considering technical aspects (radiation protection, stability, soil and water protection), the assessment of the required remedial action also takes regional and local development interests into account. But immediate measures to eliminate risks, such as recent surface subsidence, must be promptly integrated into the remediation work and implemented in a timely manner.

A total of 343 project applications have been submitted since the remediation of the abandoned Wismut sites in Saxony began in 2003. Of this total, 275 had been successfully completed by the end of 2020. The completed projects were implemented across 43 towns and municipalities and include the following underground works:

- Taking corrective action at sites affected by surface subsidence,
- Sealing open shafts and adits,
- Securing near-surface mine workings, and
- Improving water drainage in former uranium ore mines.

Above ground, the priorities are:

- Remediating radiological legacies,
- Stabilising waste rock piles and covering their surfaces, and
- Removing the structural remains of uranium ore mining operations.

After remediation the Saxonian uranium mining legacies can be sustainably re-used as industrial, agricultural or park and recreational areas.

6. Building confidence through excellence in remedial design and action

Regular publications and sharing expertise ensure transparency and acceptance

Until 1990, the uranium ore mining company Wismut was a supplier of raw materials for the Soviet nuclear armaments programme during the Cold War. For many decades, uranium ore mining operations in Saxony and Thuringia showed complete disregard for the public's well-being and the environment. The company was a state within a state; all its activities were shrouded in the strictest secrecy.

Due to this policy of secrecy that SAG/SDAG Wismut had followed for decades, in 1990/91 Wismut GmbH also faced strong reservations and mistrust from the public, the media and the regulatory bodies then under establishment. The newly established remediation company made the headlines almost daily in negative news reports in the regional and national media.

Gradually building trust through a goal-oriented and transparent information policy was therefore of the utmost importance. Municipalities, districts, regulatory bodies, experts and environmental groups were involved in the process of developing remediation concepts, identifying remediation goals and outlining proposals for the reuse of reclaimed properties. These measures – and, above all, successful, externally visible remediation work – led in time to a broad acceptance that the company still enjoys today.

Thanks to the results of its many years of work, Wismut GmbH is now perceived as an efficient remediation company. Since 1991, more than 1.7 million visitors from Germany and abroad have travelled to the remediation sites in Saxony and Thuringia to see the progress achieved for themselves. Among the outstanding events were the presentation as part of the Expo 2000 world exhibition, the 2007 National Horticultural Exhibition in Gera/Ronneburg, and the awarding of the 2008 Saxon State Prize for Building Culture to Wismut GmbH and the municipality of Bad Schlema for their joint submission, "From Death Valley to Spa Town". Since 2019, the renatured waste rock pile landscape (including waste rock pile 366 in Aue-Bad Schlema) and shaft 371 in Hartenstein have formed part of the UNESCO World Heritage Site. Wideranging public relations work will continue to be a crucial component of the remedial efforts undertaken by Wismut GmbH.

In the course of the remediation activities, the company's employees have acquired vast scientific and technical know-how and developed state-of-the-art remediation technologies of their own. Since the mid-1990s, demand for the company's experience has been growing from external, mainly international clients.

Opening event at the international WISSYM 2019 conference in Chemnitz

The services provided by Wismut experts on these external projects focus mainly on the following areas:

- Preparing remediation concepts and expert opinions,
- Drafting planning and tendering documentation,
- Overseeing construction works,
- Providing services in the fields of radiation protection, environmental monitoring and data management,
- Delivering training and continuing professional development programmes, and
- Providing auditing and project support services.

Wismut's activities in environmental remediation have made the company an internationally significant benchmark project for forward-looking technologies for the remediation of radioactive legacies. The company has presented its extensive knowledge and experience at a multitude of seminars, congresses and workshops at the national and international levels, and Wismut itself now organises international events on current issues relating to mining remediation. Wismut's WISSYM symposium has established itself as an international conference that attracts experts from around the world to Germany. Prominent partners include the U.S. Department of Energy (DOE) as well as institutions and companies from Canada and Australia. These forums are also attended by Eastern European and CIS countries, which, like Wismut, are dealing with the legacies of their former uranium industries.

Since 1999, numerous industry peers from across the globe have taken advantage of the opportunities for study visits at Wismut or attended training courses as part of a broad spectrum of international projects and programmes. In total, the company has welcomed far more than 200 experts from all over the world. The company's experts have shared their knowledge on training courses organised by the International Atomic Energy Agency (IAEA), including in Brazil, Kuwait, Moldova, Namibia, Turkey and Ukraine.

7. The historical significance of Wismut

From the art collection: In der Kaue [In the Pithead Building] by Jost Giese

More than 40 years of uranium mining operations in Saxony and Thuringia and the globally unparalleled environmental remediation project initiated after the political transformation in 1990 have intervened in the lives of local people in diverse ways and have profoundly changed the region's landscapes several times over. The federally owned company Wismut GmbH is now in possession of extensive collections, documents, facts and figures about this era. Preserving this information, making it accessible and communicating it to future generations, or presenting it to the public, is imperative.

Wismut's heritage has a multitude of different facets. The material archival holdings include the company archive with a unique art collection, an extensive collection of photographs and films, as well as the geological archive formed of the Wismut collection of ore deposit samples. The exhibition of the ore deposit samples alone encompasses approximately 1,800 exhibits in the form of minerals, rock samples and documentation from uranium ore mining operations in Saxony and Thuringia. In addition, there are extensive collections of documents concerning prospecting activities and the

The collection of ore deposit samples and the company archive form part of Wismut's heritage

extraction of raw materials between 1945 and 1990. Some 4,300 works of art (paintings, drawings, prints) by around 480 visual artists bear witness to the cultural activities of SDAG Wismut and are now owned by Wismut GmbH. The landscapes and mining traditions shaped by uranium ore mining and the subsequent remediation also form part of Wismut's heritage. In addition, there are further collections of documentation and archival materials in state archives, such as the Federal Archives, and in the collections maintained by the mining heritage associations linked with the company.

Coming to terms with the political and cultural history of SAG Wismut and SDAG Wismut, their significance in world history, and their embroilment in geopolitical conflict is essential. To prevent this important part of German history from falling into oblivion, the company sees exploring the history of Wismut and its legacy as part of its extensive research and documentation work.

Documenting Wismut's history

The history of Wismut was compiled for the Chronik der Wismut (Wismut Chronicle) and published for the first time in 1999. The chronicle describes the period of active mining operations until its cessation in detail. It also covers the impacts on the environment, the economy, social life and the health of employees and the local population, as well as examining the extremely complicated transition period at the time of reunification and the early remediation activities. In 2010, the chronicle was continued with data and experiences from the next chapter in the history of the remediation work.

In 2011, a two-volume collection of documents was published on the history of uranium ore mining by Wismut in Saxony and Thuringia and on the remediation results achieved after 1990 by Wismut GmbH. The publication was made possible thanks to support from the Federal Ministry for Economic Affairs and Energy (now BMWK), Chemnitz University of Technology, the Gerda Henkel Foundation, the Friedrich Ebert Foundation, the Institute for Contemporary History Munich and Wismut GmbH. An international team of historians studied and documented political, economical, environmental and social aspects. International comparisons were drawn with the aim of contextualising and evaluating Wismut's history, particularly with regard to its business regime, the level of sophistication of its mining engineering, environmental and radiation protection and safety standards, as well as its economic viability and employee social benefits. The resulting documentation – Mining during the Cold War – Wismut in the Soviet Nuclear Complex – constitutes an important reference work on Wismut's company history.

A witness to uranium ore mining and World Heritage – shaft complex 371

Wismut's heritage

In 2015, the Federal Ministry for Economic Affairs and Energy launched an initiative with the aim of developing a concept for the future stewardship of the extensive heritage of Wismut GmbH. An important milestone was reached in 2017, when the Federal Government, the two affected Free States of Saxony and Thuringia, and Wismut GmbH signed a memorandum of understanding in which they agreed to "develop and implement a heritage concept commensurate to the history and significance of Wismut".

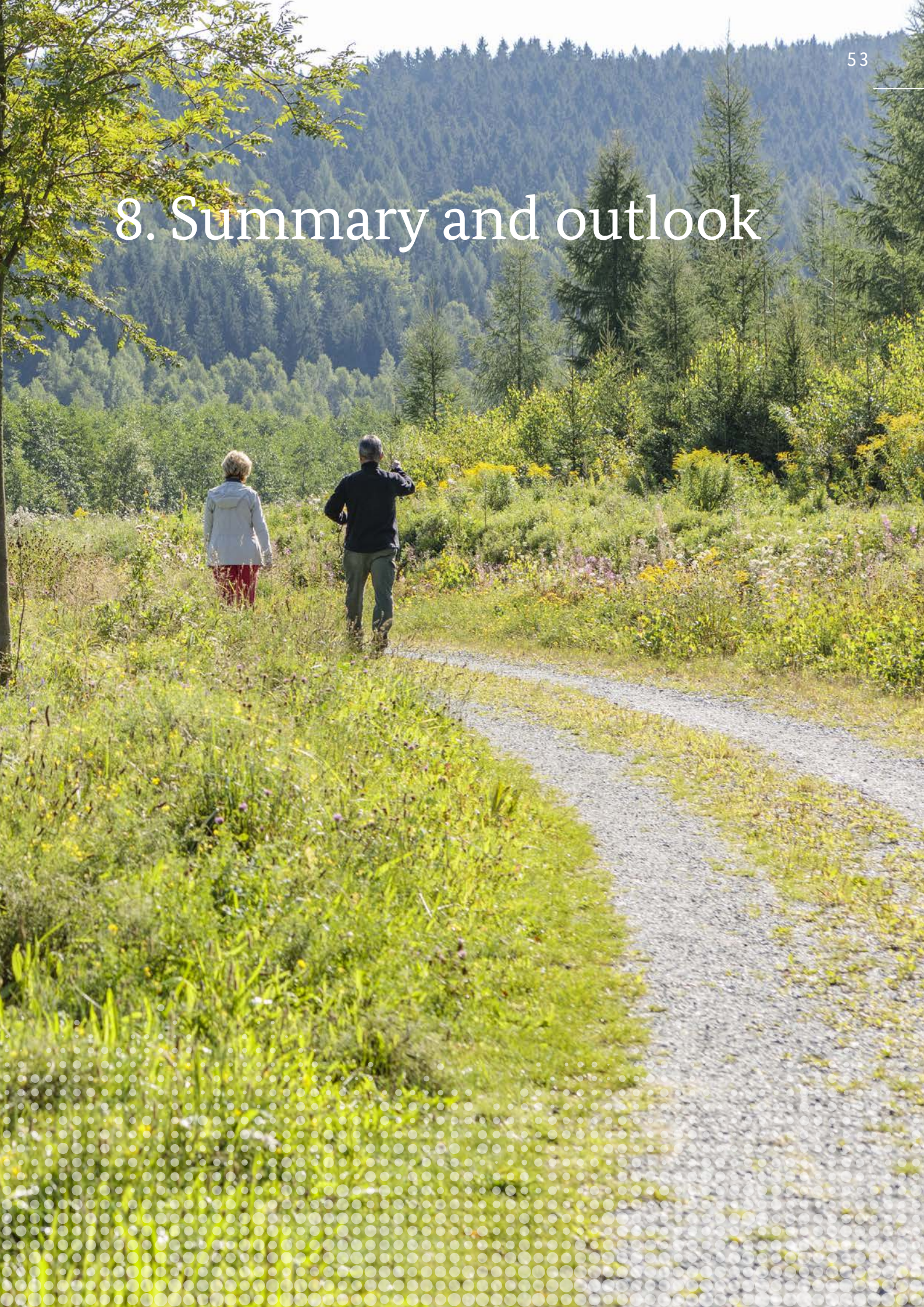
Following extensive discussions with researchers, regulatory bodies and interest groups, the German Mining Museum in Bochum drew up the implementation concept on behalf of Wismut. In 2021, Saxony, Thuringia, and the Federal Government signed an administrative agreement with the aim of not only preserving Wismut's heritage, but also researching, presenting and communicating it. A subsidiary of Wismut GmbH specifically devoted to this purpose – Wismut Stiftung gGmbH – was founded at the end of 2021. Concurrently with this, the Saxon Academy of Sciences in Leipzig agreed to initiate and explore multidisciplinary research into Wismut's heritage.

Wismut as a component of the UNESCO World Heritage Site

The Erzgebirge/Krušnohoří Mining Region has held UNESCO World Heritage status since July 2019. The region comprises 22 components in total, 17 sites in Germany and five in the Czech Republic. Together, they provide a vivid insight into a cultural and historical landscape irrevocably shaped by mining. The uranium ore mining landscape constitutes one component of this UNESCO World Heritage Site and represents the extensive mining operations of the former SDAG Wismut, which left their mark across large swathes of the western Erzgebirge region.

Three components of Wismut GmbH are inscribed in the list of UNESCO World Heritage. The period of uranium ore mining is documented by shaft complex 371 – once the most important shaft in the former Aue mining unit – and by the renatured waste rock pile landscape at Bad Schlema, including waste rock pile 366. The third Wismut component of the World Heritage Site is the Markus Semmler adit, which was mentioned in historical records as long ago as 1503. In the second half of the 20th century, the adit served as the first major exploratory mine for uranium ore mining by SAG/SDAG Wismut and and was set as reference level for all levels of the underground mine. Till to date it drains the entire area of the underground mine districts of Schlema, Schneeberg and Schneeberg-Neustädtel.

8. Summary and outlook



Upon the cessation of uranium ore mining in 1991, the Federal Government assumed a special responsibility for rehabilitating the legacies of the former uranium ore mining operations at all sites in Saxony and Thuringia, thus making a significant contribution to shaping the future of the affected regions and their people. Thanks to the work of the company's employees and great support from the spheres of politics and business – in some cases extending far beyond the borders of Saxony and Thuringia – the majority of the remediation measures have been implemented with manifestly successful results. Completion of the still pending tasks is within sight.

It is currently anticipated that substantial remediation work will be essentially finished by 2028. The duration of the subsequent long-term tasks – the interception and treatment of flood water and seepage, tending to the covered areas at waste rock piles and tailings management facilities, the operation of a comprehensive environmental monitoring system and mine inspection work – cannot be predicted exactly today.

The remediation of former mining areas and their reuse have paved the way for the region's economic development and for attracting jobs to the area. Ongoing work at the abandoned Wismut sites in Saxony will give the municipalities further opportunities to sustainably reuse the reclaimed land.

To date, Wismut GmbH has already made some 1,400 hectares of rehabilitated properties available for reuse. This land is now being used for forestry, agricultural, public and commercial purposes, in addition to providing habitats for a large number of animals and plants. Wismut GmbH is documen-

ting the process of biological repopulation and development through a variety of ecological studies, such as biomonitoring.

Further details on the remediation work can be found on the Wismut GmbH website (www.wismut.de), where you will also find other information and numerous other publications on Wismut.

Diverse forms of reuse: Viewpoint on the Schmirchauer Höhe (Schmirchau Heights; 2020) and grazing at the Trünzig tailings management facility (2014)