

nagra ● we care

**annual report
2019**

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Foreword



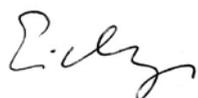
**Corina Eichenberger,
President of the Board of Directors**

The deep borehole campaign is in full swing and public interest is great: in 2019, almost 2000 visitors looked over Nagra's shoulder on a tour of the drill sites. Aside from the deep boreholes, last year's focus was on the placement of the surface infrastructure of a deep geological repository. From our point of view, these facilities are of regional importance, and the surface infrastructure project has to be developed in an environmentally, socially and economically compatible manner. After Nagra published its proposals in the spring, the siting regions and Cantons started their evaluation.

The surface infrastructure also includes the encapsulation plants for radioactive waste. At the end of 2018, the Federal Council decided that Nagra, in collaboration with the regional conferences and siting Cantons, could consider whether it would also be possible to locate these facilities outside the siting regions. In 2019, the suggestion was made to place them at the site of the interim storage facility in Würenlingen. It was also announced that sites at the Leibstadt and Gösgen nuclear power plants were to be assessed. In November, however, both nuclear power plant operators informed the Swiss Federal Office of Energy that, after preliminary investigations, they had decided not to pursue specific proposals for an encapsulation plant on their terrain. As it is not possible at present to say with any certainty when the deep geological repository will go into operation, there is no guarantee that synergies will still arise with nuclear facilities at these sites.

At the end of Stage 3 of the Sectoral Plan process, the fundamental political decision on the site for a repository in Switzerland will be made with the general licence. We have three promising siting regions and I am very curious to find out what insights the deep borehole investigations will deliver.

My sincere thanks go to the members of the Board of Directors for their constructive cooperation. I would also like to thank the Executive Board and all of Nagra's employees for their commitment to working towards the safe disposal of radioactive waste.



Corina Eichenberger

**Thomas Ernst,
Chief Executive Officer**

The year 2019 was defined by the deep borehole campaign that will provide key input for the safety-based comparison of the three remaining siting regions, and by Nagra's proposals for the surface infrastructure of the deep geological repositories.

At the end of November, the first deep borehole was completed in Bülach in the Nördlich Lägern siting region. The results meet the expectations. The very tight Opalinus Clay host rock was encountered at a depth of around 900 metres and has a thickness of over 100 metres. In addition, samples from all relevant geological layers were collected for further investigation, and various tests were conducted in the borehole. The results confirm that Nördlich Lägern is suitable for hosting a deep geological repository.

During the summer, drilling of the second deep borehole began in Trüllikon in the Zürich Nordost siting region and there too, initial results confirm previous findings. The impermeable Opalinus Clay does not lie quite as deep as in Bülach but has a similar thickness. As with the previous borehole in Benken, the results from Trüllikon confirm that Zürich Nordost is suitable for hosting a repository. On a particularly positive note, the deep borehole campaign has proceeded without any legal constraints, further indicating the broad acceptance of the scientific investigations being conducted in the search for the safest site.

In May, Nagra announced its proposals for placing the surface infrastructure. Aside from the surface facility, this includes operations and ventilation shafts. The proposals form an important basis for the collaboration with the regions and Cantons and the resulting position statements.

All those who demonstrated their great commitment to the intensive cooperation in the three siting regions deserve our sincere gratitude. I would also like to express my appreciation to the entire Nagra staff for their dedication and competent contribution towards realising safe radioactive waste disposal in Switzerland.



Dr. Thomas Ernst

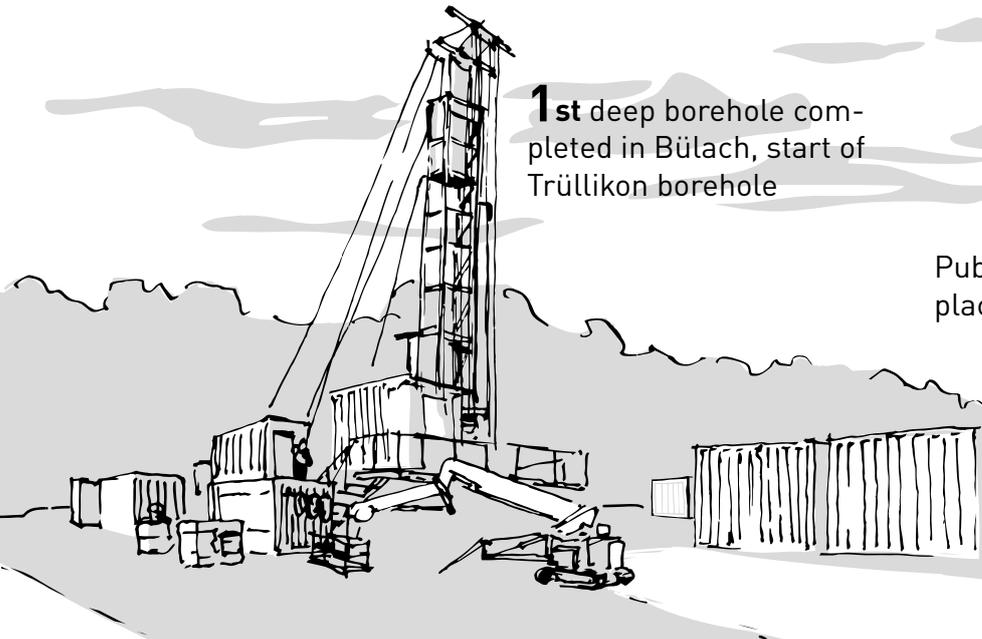




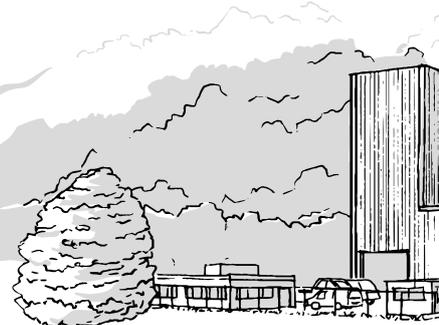
A SHORT OVERVIEW OF NAGRA

Nagra is Switzerland's national technical competence centre in the field of deep geological disposal of radioactive waste. It was founded in 1972. The waste producers are responsible for the disposal of the waste and for financing Nagra's work. The members of the Nagra Cooperative are the operators of the nuclear power plants, the interim storage facility Zwiilag and the Swiss Confederation. Out of a strong sense of responsibility for the long-term protection of humans and the environment, around 130 employees are involved daily in performing this important work.

2019 in numbers



1st deep borehole completed in Bülach, start of Trüllikon borehole



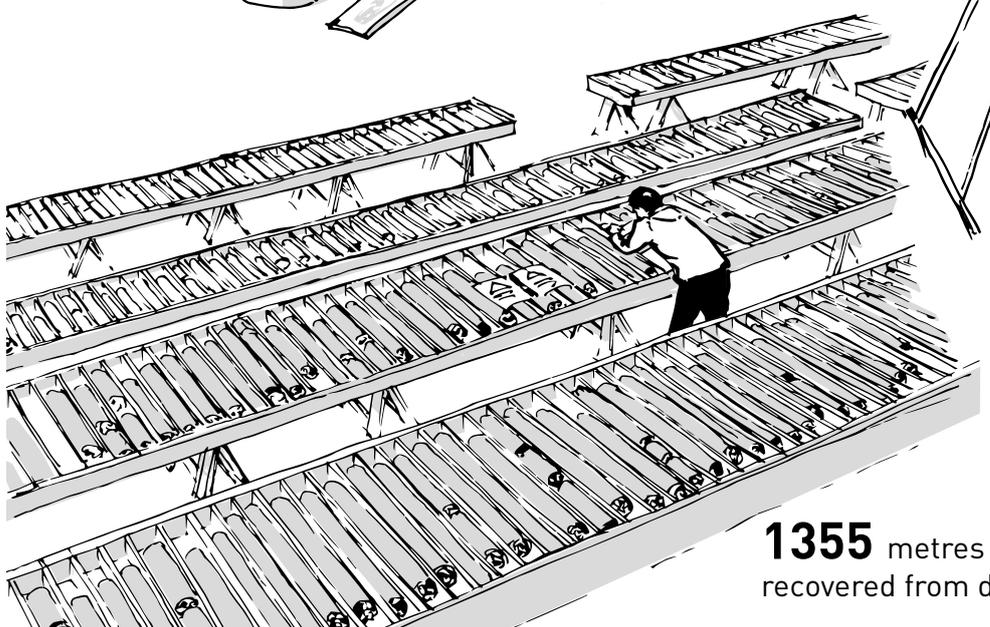
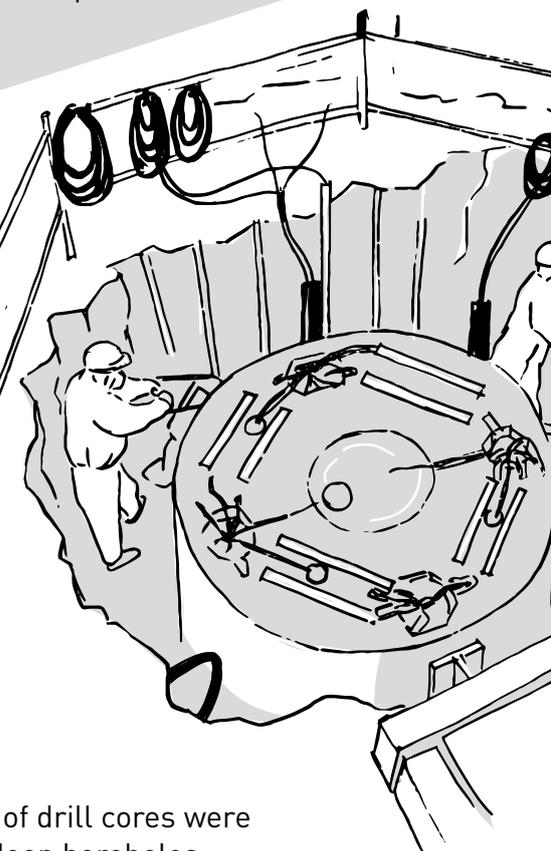
Publication of **10** proposals for placing the surface infrastructure



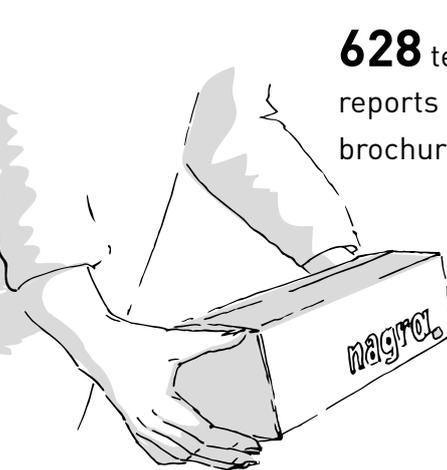
Present at **18** exhibitions in the regions



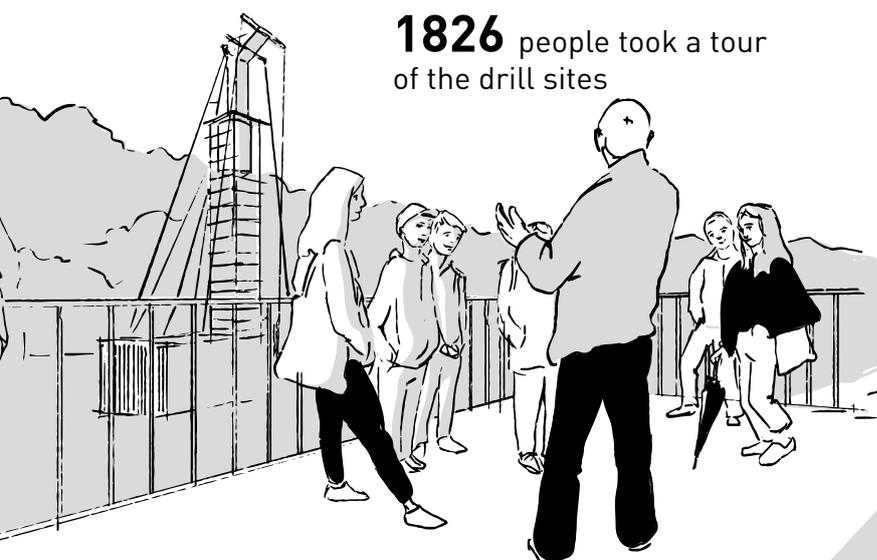
900 students learned about radioactive waste disposal



1355 metres of drill cores were recovered from deep boreholes



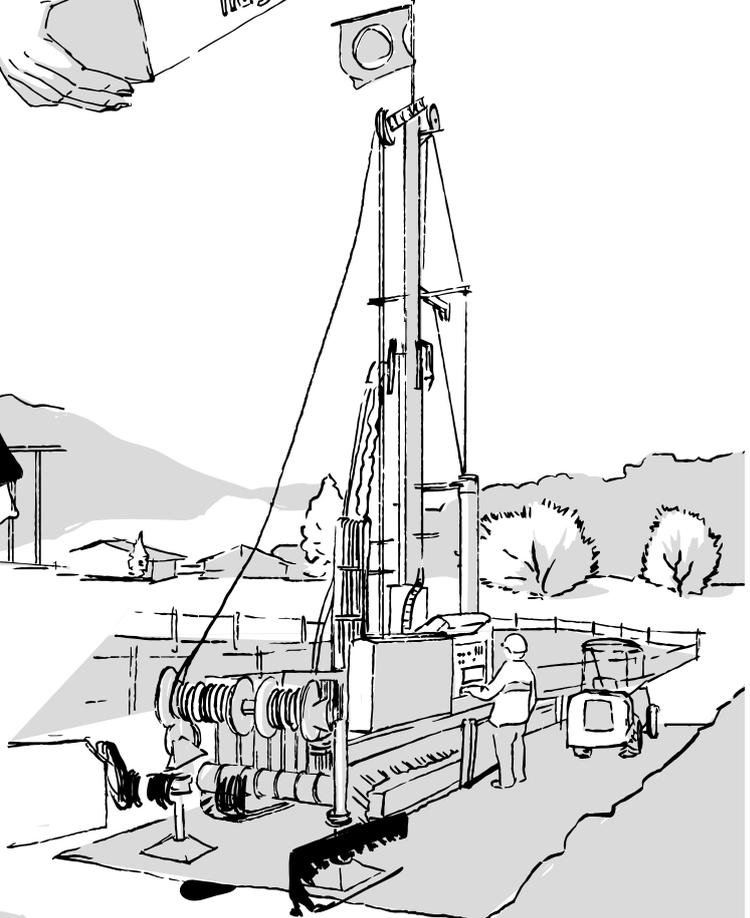
628 technical reports and work reports and **12 000** special brochures were sent out



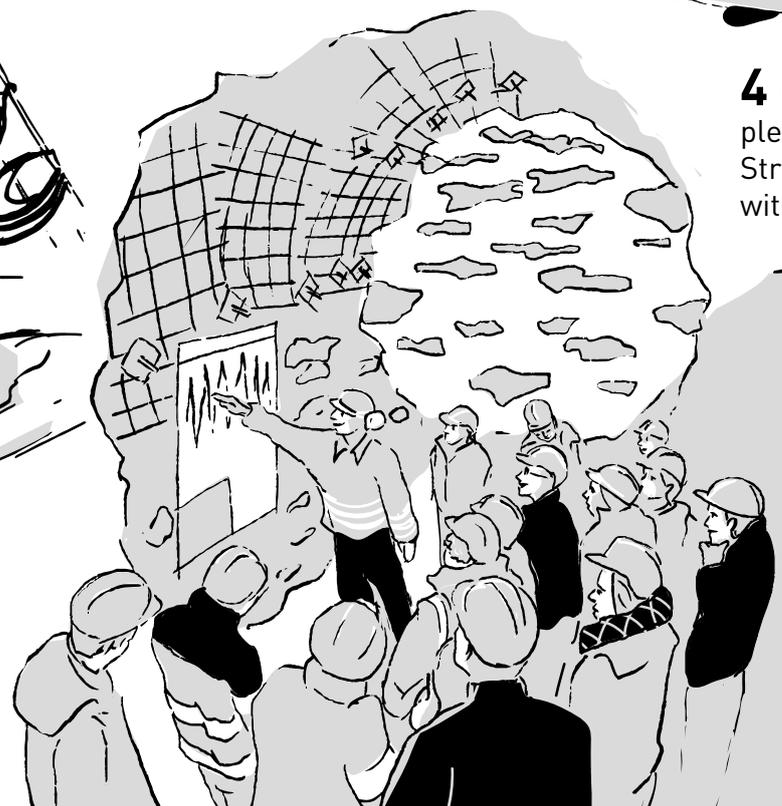
1826 people took a tour of the drill sites



35 years of research at the Grimsel Test Site



4 Quaternary boreholes were completed in 2019; Hochfelden-Strassberg was the deepest with **278** metres



5770 people visited the Mont Terri Rock Laboratory and the Grimsel Test Site

Guiding principles of waste

How is waste management regulated by law, and what are the concepts for waste management and financing? This section provides answers to these questions.

Legal framework

The waste producers must ensure that radioactive materials are handled in such a way as to minimise waste production, and the resulting waste must be safely disposed of. The relevant legal provisions are contained in the Nuclear Energy Act and the Nuclear Energy Ordinance. The overarching principle is the long-term protection of humans and the environment. All radioactive waste must be disposed of in deep geological repositories in Switzerland.

In line with the polluter pays principle, the waste producers are responsible for covering ongoing costs as well as for financing the decommissioning of the nuclear installations and disposal of the resulting waste.

The Federal Government has defined the criteria and procedures applying to site selection in the Sectoral Plan for Deep Geological Repositories; the Sectoral Plan also regulates public participation. The procedures for granting general, construction and operating licences for a repository are focused at the federal level. The general licence is subject to a parliamentary decision and an optional national referendum. Participation of the siting Cantons, neighbouring Cantons and neighbouring countries in the process is required by law.

In accordance with the revised Nuclear Energy Act that entered into effect on 1st January 2018, no new nuclear power plants can be constructed, but existing ones can continue to operate as long as they are safe. Exporting spent fuel assemblies for reprocessing is also prohibited. At the end of 2019, the Mühleberg nuclear power plant was taken off the grid. The operator, BKW Energie AG, assumed that the retrofits required by the Federal Government as a condition for long-term operation would not have been worthwhile.

Approach to waste management

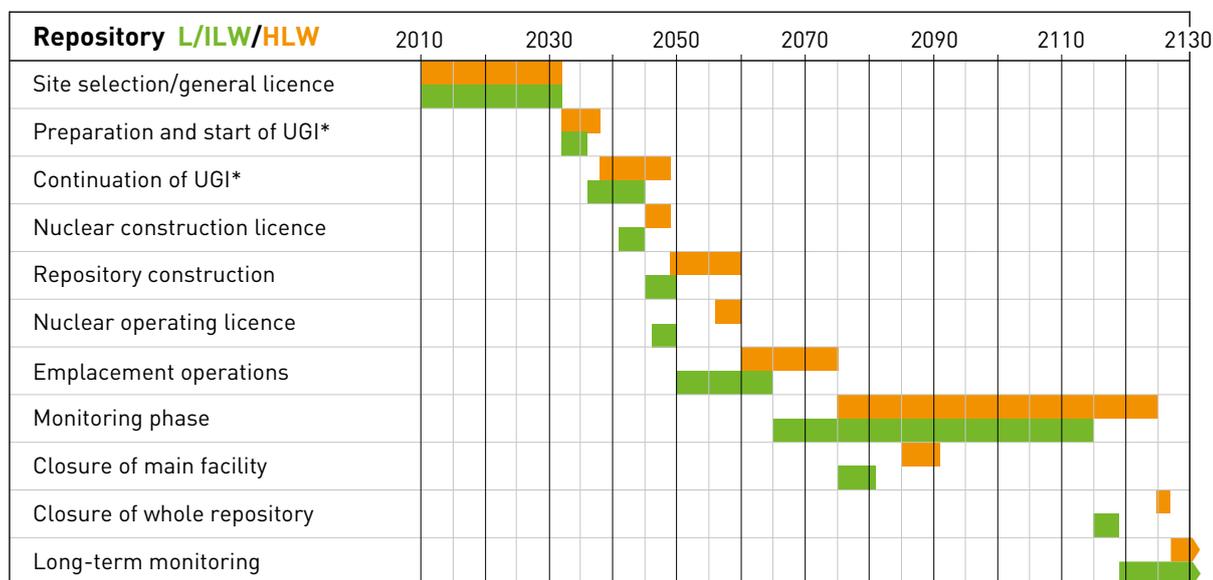
Nagra's two feasibility demonstrations for low- and intermediate-level waste (L/ILW) and high-level waste (HLW) were approved by the Federal Council and show that safe deep geological repositories can be constructed in Switzerland. The Waste Management Programme describes the procedures for the planning, construction, operation and closure of deep geological repositories. It also includes information on origin, types and volumes of radioactive waste, its allocation to the repositories and the repository design. In addition, it contains a realisation plan for the repositories, a financing plan and information on the duration and capacity of interim storage. The elements of Nagra's information concept are also described.

Nagra has to update the Waste Management Programme every five years and submit it to the federal authorities. In 2016, Nagra submitted the most recently updated Programme as well as its Research, Development and Demonstration Plan, along with swissnuclear's Cost Study. The Waste Management Programme was approved by the Federal Council in December 2018 and Nagra will submit the next Programme in 2021.

In Switzerland, radioactive waste and materials arise from the production of nuclear energy in the nuclear power plants and from applications in medicine, industry and research. The waste is continually prepared for interim storage or deep geological disposal and is characterised and inventoried. As L/ILW and HLW have different properties, they have to be disposed of in separate emplacement rooms: in a repository for L/ILW and in one for HLW. These can be realised as a combined repository at the same site or as individual repositories at two different sites.

Nagra has prepared realisation plans for the L/ILW and HLW repositories (see Figure). They describe the basic sequence of activities and outline the work that has to be done up to the closure of the repositories.

management



* UGI = Underground geological investigations

Realisation plan for the L/ILW and HLW repositories based on current planning

Securing the funding

The Waste Disposal Fund secures the costs of disposal and reprocessing of radioactive waste from the nuclear power plants. The Decommissioning Fund covers the decommissioning and dismantling of the nuclear facilities as well as the disposal of the resulting waste. The operators of the nuclear facilities contribute to both Funds, which are under federal supervision. For electricity generated with nuclear power, the consumer pays around 1 Rappen (= cent) per kilowatt hour to finance decommissioning and waste disposal. At the end of 2019, the accumulated capital in the Waste Disposal Fund amounted to around CHF 5.8 billion and in the Decommissioning Fund to around CHF 2.7 billion. More detailed information can be found on the website of the Funds (www.stenfo.ch (Documentation > Search > Topic Financial results)).

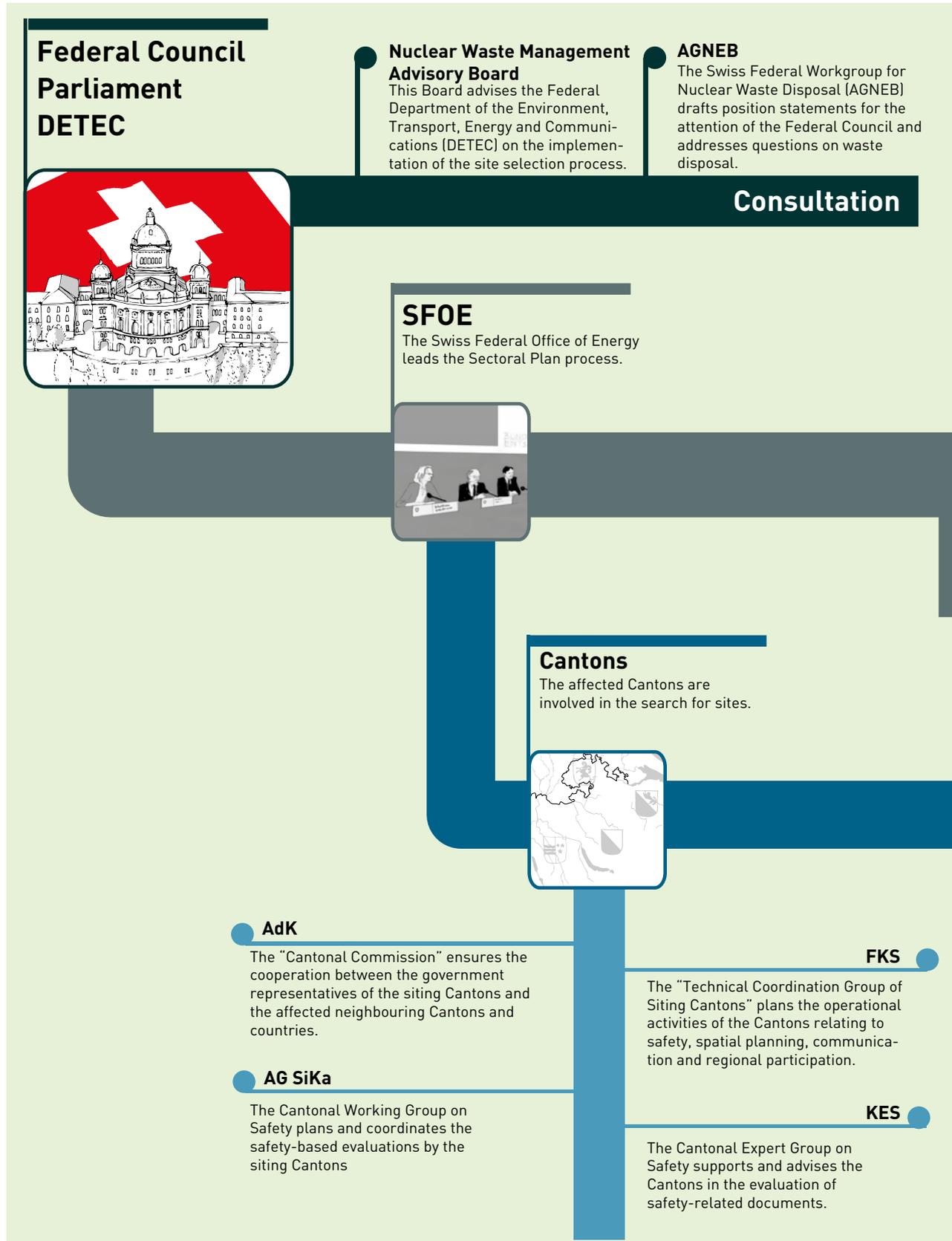
A feature of the currently valid Cost Study 2016 submitted by swissnuclear is the consideration of cost surcharges for risks and inaccuracies in predictions. The cost estimate forms the basis for determining the contributions to be paid by the operators of the power plants into the Decommissioning and Waste

Disposal Funds. The Federal Government is also a member of the Nagra Cooperative and makes annual contributions to costs for disposal of wastes arising from applications in medicine, industry and research on the Government's behalf. New calculations show that these contributions have been too low for years, because the volume of federal waste is considerably larger than originally assumed. The Federal Council therefore decided to settle the federal debt accumulated up to 31st December 2019 with a one-off payment to Nagra in 2020 and to adjust the annual contributions of the Federal Government.

In November, the Federal Council decided on a revision of the Decommissioning and Waste Disposal Fund Ordinance (SEFV), which entered into effect on 1st January 2020.

In Switzerland, the search for a repository site is regulated

Many actors are involved and responsibilities are clearly separated.



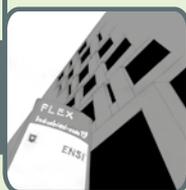
lated in the Sectoral Plan for Deep Geological Repositories.

Sectoral Plan for Deep Geological Repositories

The Sectoral Plan process has three stages. Numerous bodies participate in the process, which is under the lead of the SFOE. Cantons and communities are involved, as are neighbouring countries, interested organisations, associations, political parties and the public. Nagra develops the technical and scientific foundation, proposes siting regions and sites and, in Stage 3, submits the general licence applications for the repositories. The Swiss Federal Nuclear Safety Inspectorate (ENSI) reviews Nagra's proposals from the perspectives of safety and engineering feasibility. For this, it consults external experts. Following the consultation and participatory processes, the responsible authorities and the Federal Council make an overall assessment at the end of each stage.

ENSI

As the regulatory authority, the Swiss Federal Nuclear Safety Inspectorate monitors the site investigations.



Nagra

The National Cooperative for the Disposal of Radioactive Waste has the task of planning and realising safe waste disposal in deep geological repositories.



Main actors

TFS

The Technical Forum on Safety discusses and answers technical and scientific questions raised by interested parties and the public.

Regional conferences

The regional conferences form the core of regional participation, giving communities, organised interest groups and the public a platform where they can raise their concerns.



Neighbouring countries

The affected neighbouring countries are represented in different bodies.



Further participants

Communities

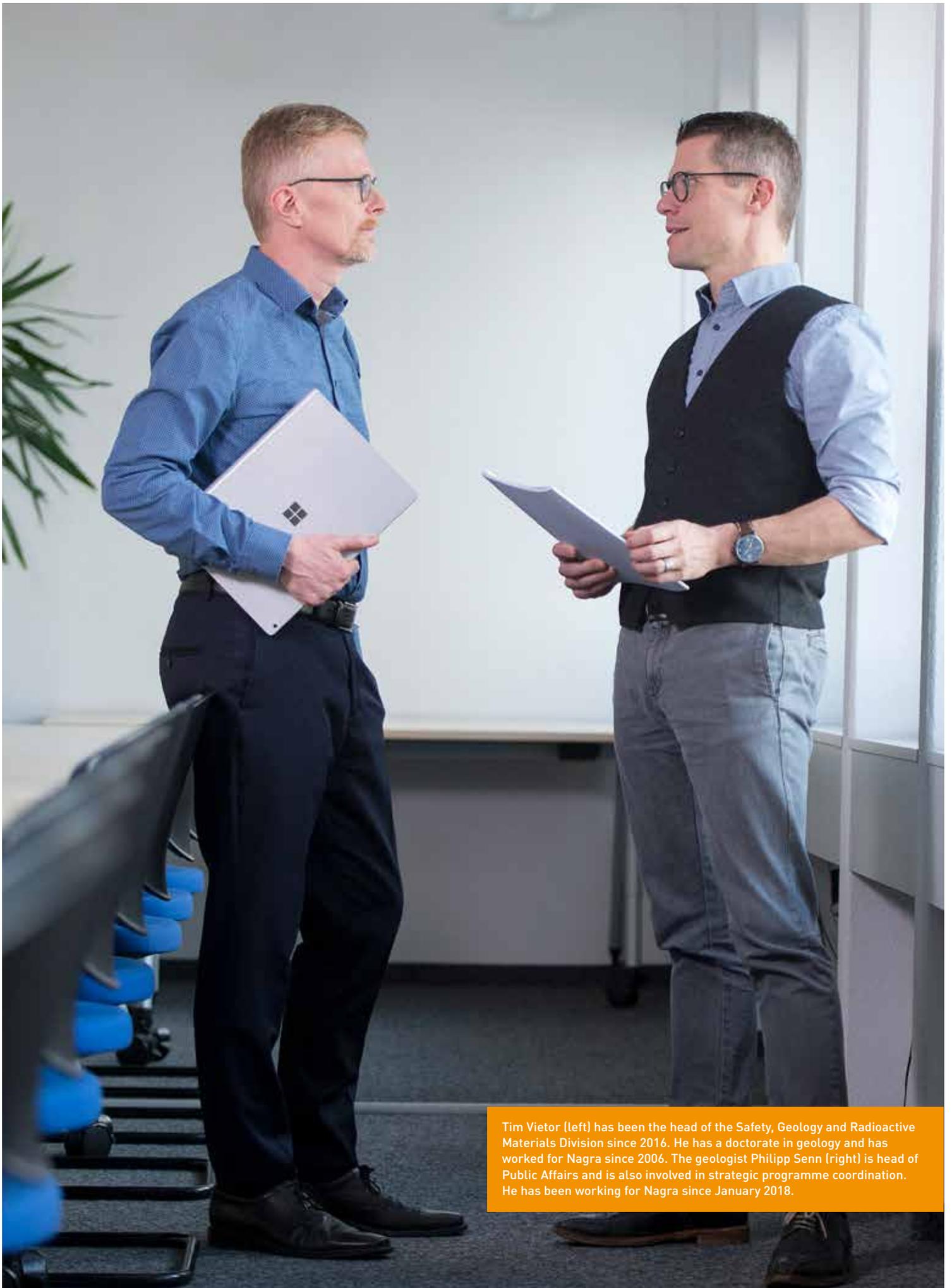
Political parties

Interest groups

Associations

Public





Tim Vietor (left) has been the head of the Safety, Geology and Radioactive Materials Division since 2016. He has a doctorate in geology and has worked for Nagra since 2006. The geologist Philipp Senn (right) is head of Public Affairs and is also involved in strategic programme coordination. He has been working for Nagra since January 2018.

Current status of work

Tim Vietor and Philipp Senn respond to questions on the work carried out in 2019 and on upcoming tasks.

What geological insights have been gained from the deep borehole and Quaternary borehole investigations?

Tim Vietor: The deep boreholes in Bülach and Trüllikon essentially confirmed our expectations: the Opalinus Clay layer has only a few fault zones, is over 100 metres thick, shows quiet bedding and has a low permeability. This is good news from the point of view of long-term safety. While drilling in Bülach, we identified a fossilised coral reef. Initial tests conducted in the borehole indicate that the permeability in the vicinity of the reef is also low, and it does not lie directly above the Opalinus Clay. A rock formation with a high clay content lies between the reef and the Opalinus Clay, and the reef thus does not present a problem with regard to long-term safety. Whether this will be a key differentiating factor for site selection can only be answered after the remaining siting regions have been investigated and data are available for all relevant selection criteria.

In 2019, we conducted further Quaternary borehole investigations in the Nördlich Lägern and Zürich Nordost siting regions to explore unconsolidated rocks that were deposited by glaciers, rivers and lakes. These can be found, for example, in troughs that were carved into the Earth's surface by glaciers. We drill Quaternary boreholes to investigate these troughs. The results of the investigations are as expected and the presumed depth of the troughs was, with a few exceptions, largely confirmed. The lake deposits found in the troughs are suitable in principle for applying dating methods. We have also learned a few technical lessons: we can now retrieve very good quality drill cores from greater depths up to 270 metres that we are analysing further. Aside from the Quaternary boreholes, we also investigate gravel deposits at the surface that were laid down by rivers.

Why does Nagra invest so much effort in exploring erosion in the past?

Tim Vietor: We have to look at how a high-level waste repository evolves over a time period of one million years. Ice ages followed by warm periods will continue to occur in the future and define the landscape. We include the landscape evolution in our considerations and are interested in processes that could

affect the safe containment of waste in a repository. This applies in particular to erosion. Investigating erosion processes allows us to understand how the landscape has evolved over the last approximately two million years. Based on this, we can predict future evolution. The safety of a deep geological repository also depends on how well it is protected by the overlying rock formations.

“We presented the results of our extensive research on the geology of Northern Switzerland to the authorities. It motivates us to know that we are on the right path.”

Tim Vietor

We have to evaluate to what extent these formations are removed by erosion. We study this with field investigations such as Quaternary boreholes as well as laboratory experiments and modelling studies. Finally, we will be able to say which site is best and demonstrate that the selected site meets the safety requirements of the regulatory authorities. We are convinced that our work on erosion and on other topics will form a solid basis for decision-making.

How important is the worldwide collaboration with other researchers?

Tim Vietor: For one, the methods we apply to investigate unconsolidated rocks and sediments draw on worldwide expertise. We also work together with research teams to investigate regions around the world where glacial erosion plays a role. We commission studies, for example, in New Zealand, Patagonia, North America and Scandinavia. This allows us to correctly understand the landscape features of Northern Switzerland and their evolution. As the glacial retreat from the Swiss Plateau occurred several thousand years ago, human settlement and agriculture have since changed the landscape significantly. By contrast, our studies abroad focus on areas with recent glacial retreat, and we can observe phenomena as they occur.

On which aspects of erosion research do you expect most progress?

Tim Vietor: Switzerland has few deposits dating back to the beginning of the ice age, i.e. over one million years ago. Many of these deposits, and hence information on their evolutionary history, have already eroded. In addition, it is not always easy to date these deposits, especially in the case of sediments that are older than around 50 000 years, for which we have to apply complex dating methods. However, we are confident that combining numerous methods and investigating many different deposits will provide us with a sufficient overview of Switzer-

land's erosion history over the last approximately two million years. Based on this, we can make predictions for the future. To do so successfully, we use the best available know-how in line with the current state of the art in science and technology.

In May 2019, Nagra published its surface infrastructure proposals for the different siting regions. How has the discussion in the regions gone so far, and what lessons can be learned?

Philipp Senn: The discussion surrounding the concretisation of the surface infrastructure is complex, and our technical report forms the basis for the ongoing work. In my opinion, the on-site inspections with those involved have been particularly beneficial. The explanations that we were able to present

This regional participation is highly relevant in a major project such as a deep geological repository. In my opinion, the concerns of those directly affected have to be included into the planning at an early stage. The collaboration in Stage 2 has confirmed this, and I believe it is just as important for Stage 3 and beyond – because now, step by step, everything is becoming more concrete.

What kind of feedback did Nagra receive from the regions and Cantons on its surface infrastructure proposals?

Philipp Senn: Up till now, the working groups on the surface infrastructure have been primarily concerned with our proposals and how to evaluate them. Representatives of the Cantons also attended all the working group meetings. Whenever we were asked to do so, we supported these efforts and answered a variety of questions. However, the provisional position statements to be delivered to the Swiss Federal Office of Energy have not yet been completed.

Overall, the advantages and disadvantages of the areas proposed for the surface facilities were already known from Stage 2. Discussions have not revealed any entirely new aspects for the additional auxiliary access facilities: after all, these really are just smaller areas with a supporting function. It is still not always easy to ensure that everyone involved is on the same page. Clear communication is an ongoing learning process.

“What I greatly appreciate is that the discussions with the regions and Cantons have not lost momentum despite this being a drawn-out procedure with topics that are often difficult.”

Philipp Senn

to the working groups of the regional conferences were hopefully also useful. For the collaboration with the regions, it has been, and still is, our task to present the complex information as comprehensibly and transparently as possible. This cannot be accomplished in the future with just reports and sets of slides; digital datasets, images and concise information are also needed.

Personally, I see it as an achievement that the regions can participate and state their positions on certain topics concerning the site selection process.

What are the main concerns of the regions and Cantons with regard to the concretisation of the surface infrastructure?

Philipp Senn: The various participants have very different priorities. For the working groups, for example, the perceptibility or visibility of the facility from populated areas as well as the need for agricultural land are of particular importance. The top priority of the Cantons, on the other hand, is to locate the facility away from important groundwater aquifers. The positions on groundwater range from acceptance that a facility above groundwater complies with legal regulations to the opinion that it should not be built in an area with intensive groundwater usage. For the next steps in the process, it is necessary to find a consensus between the different positions of the authorities and the regions.

What is important to you personally with regard to the collaboration with the regions and Cantons?

Philipp Senn: I hope that, from a geological and engineering point of view, it will be possible to build the repository at the most suitable site in Switzerland. I also hope that we will find the best possible “regionally compatible” solution for planning and implementing the part of the facility that will be visible to the region. I find meeting and talking to everyone involved rewarding, even if the topic is not an easy one. My hope is that the exchange can remain based on mutual respect and factual discussion. Everyone involved deserves great respect for persevering.

How will the concretisation of the surface infrastructure proceed, and how does the time plan look?

Philipp Senn: The provisional statements of the regional conferences on our surface infrastructure proposals are expected for spring 2020. Up to the middle of 2020, we will compile a report on the advantages and disadvantages of placing the encapsulation plants outside the siting regions. This will form the basis for the following trans-regional collaboration. Affected regions, Cantons and neighbouring German districts will participate in this discussion. Following this, the definitive responses of the regional conferences on the con-

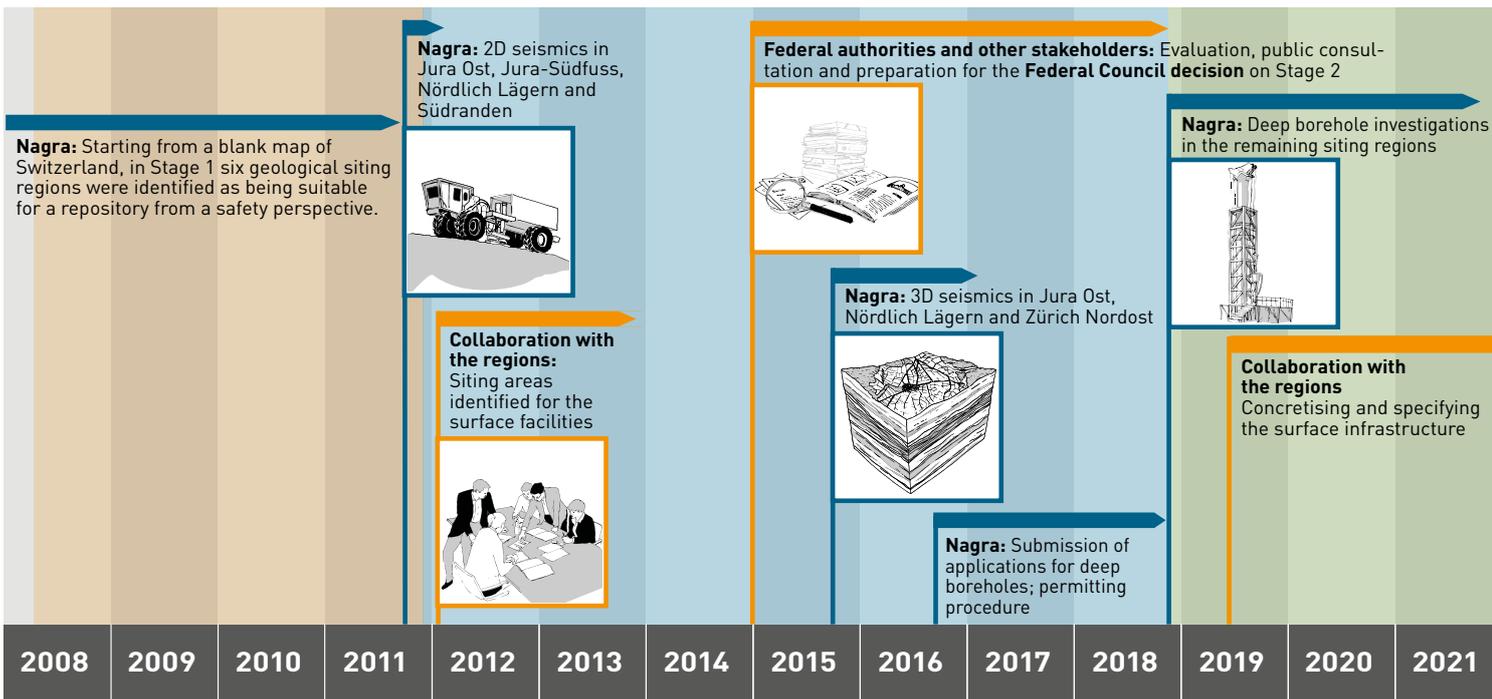
cretisation of the surface infrastructure are expected for the spring of 2021. They form an important point of reference for us as to where and how to plan the surface infrastructure in the regions. The approximate location and size of the most important elements of the surface infrastructure will be submitted together with the general licence application (see text box).



WHAT IS A GENERAL LICENCE APPLICATION?

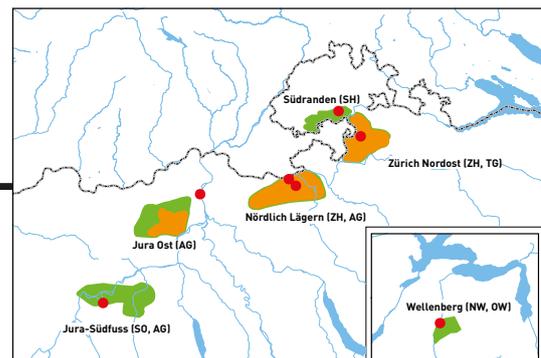
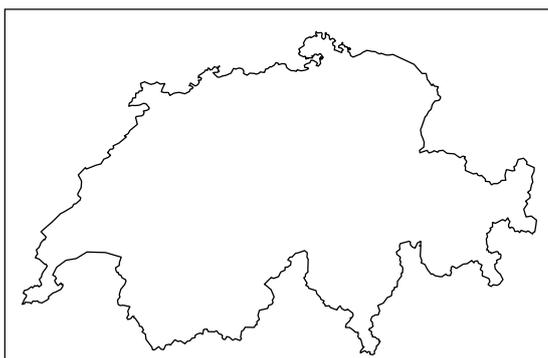
Deep geological repositories require a general licence from the Federal Council, and Nagra will submit the required licence applications. These include a description of the main features of the facilities at the proposed sites. The general licence specifies the location and the approximate size and layout of the most important facility components. More detailed descriptions of the installations, procedures and technologies will be required later for the construction and operating licence applications.

The three-stage Sectoral Plan to deep geological

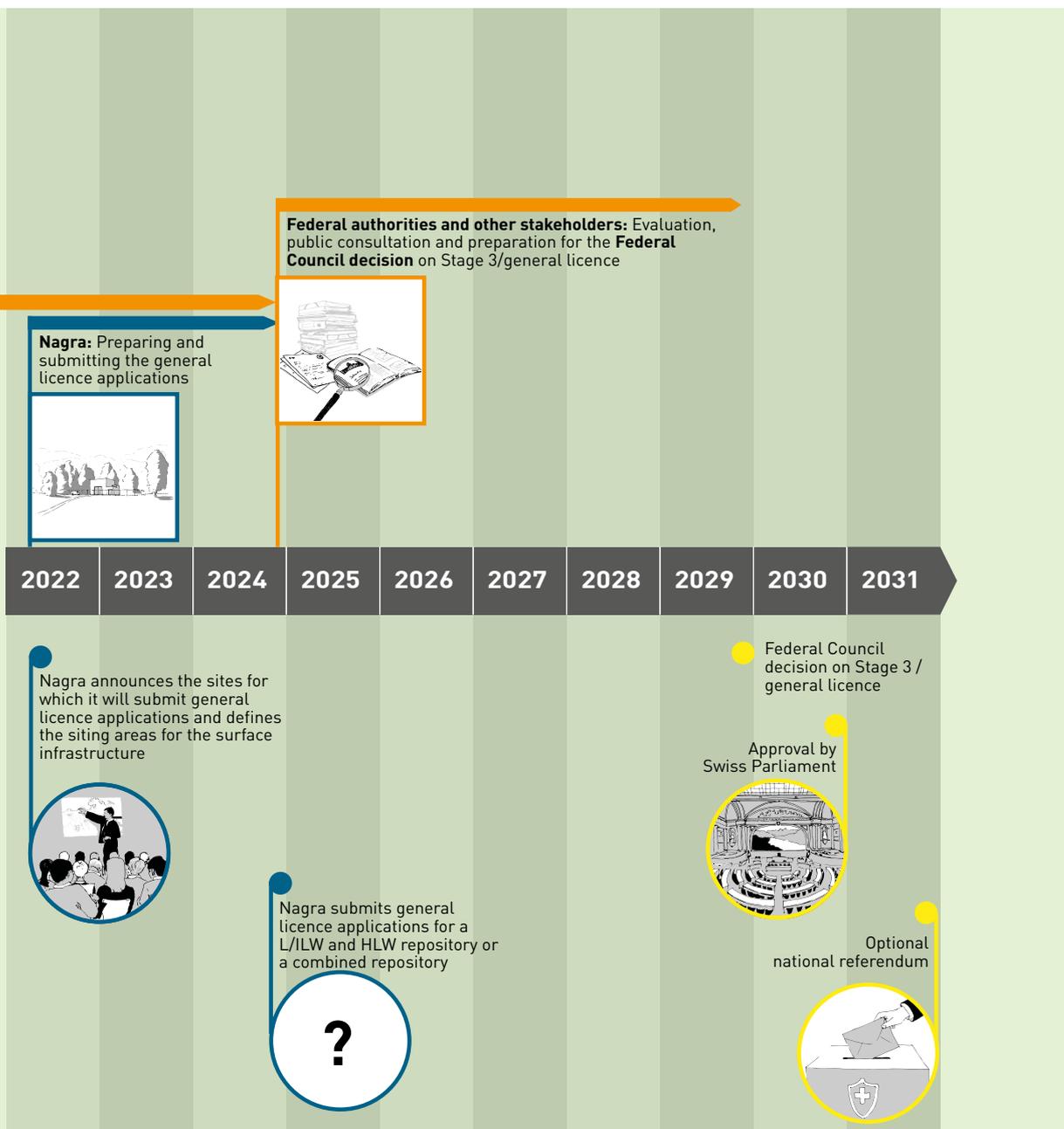


Starting-point: Blank map of Switzerland / selection criteria: safety and engineering

Federal Council decision on Stage 1



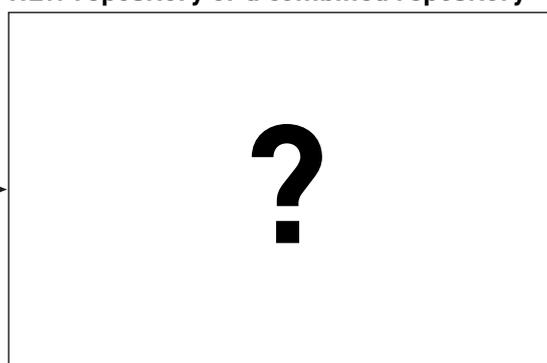
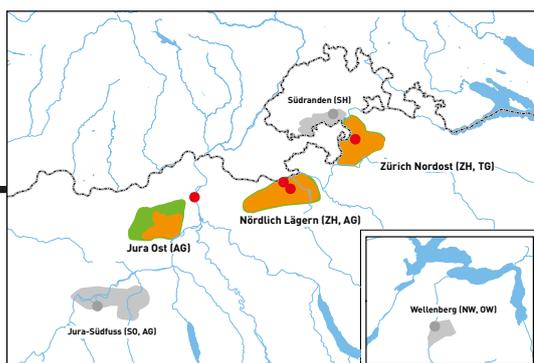
repositories: retrospective and outlook



feasibility

Federal Council decision on Stage 2

General licence applications for a L/ILW and HLW repository or a combined repository



(as of March 2020)



Nagra's deep boreholes 2019: bird's-eye view of the Bülach (above) and Trüllikon (below) drill sites.



Current status of the deep borehole campaign

Nagra is currently drilling deep boreholes to complete its picture of the underground in the three potential siting regions Jura Ost, Nördlich Lägern and Zürich Nordost. This will allow a comparison between the regions and a fact-based and transparent determination of the safest repository site. The deep boreholes were started in early 2019 and are progressing well.

First deep borehole drilled in Bülach

From April to November 2019, Nagra drilled its first deep borehole of the present campaign in Bülach in the Nördlich Lägern siting region. In parallel, a second deep borehole was started in August 2019 in Trüllikon in the Zürich Nordost siting region. The first borehole in the Jura Ost siting region began in the spring of 2020 on the Bözberg. However, it is not planned to drill all of the 23 deep boreholes applied for by Nagra. How many will actually be drilled depends on the results of the investigations.

Good rock samples

The deep borehole in Bülach reached a depth of 1370 metres. Numerous tests were conducted in the borehole and rock samples were continuously recovered. Among others, experts from the University of Bern and the Paul Scherrer Institute (PSI) are investigating these in the laboratory. During drilling, a fossilised coral reef was discovered above the Opalinus Clay. A borehole test revealed that there was no increase in permeability in this area. Initial information on the thickness, permeability and composition of the Opalinus Clay in which the repository could eventually be constructed is now available: in Bülach, the clay layer is around 104 metres thick and lies at a depth between 892 and 996 metres. Properties such as the composition and tightness of the Opalinus Clay are comparable with results from earlier boreholes conducted in Northern Switzerland.

While drilling, precautions have to be taken to make sure that the borehole stays open for testing and that borehole wall breakouts do not occur. In the lower section of the Opalinus Clay in the Bülach borehole, this was not entirely successful and, as a result, it was not possible to conduct all tests as planned. Optimising the drilling techniques allowed

a recurrence of this to be avoided in Trüllikon. This included modifying the casing concept and the composition of the drilling fluid compared to Bülach.

“It is not planned to drill all 23 boreholes applied for. How many will be drilled depends on the results of the investigations.”

Trüllikon-1 deep borehole: on track

By the end of the year, drilling in Trüllikon had advanced through the Opalinus Clay to a depth of 973 metres. In Trüllikon, the Opalinus Clay layer is over 112 metres thick and lies at a depth between 816 and 928 metres. Starting at a depth of 500 metres, drill cores were recovered continuously and different tests in the borehole could be performed as planned. First results correlate very well with the results of the borehole drilled in Benken from 1998 to 1999 and with the 3D seismic investigations conducted in Zürich Nordost in 2016. The borehole was completed in March 2020.

Further deep boreholes

The first deep borehole in the Jura Ost siting region will be Bözberg-1. The drill site was largely constructed by the end of 2019. The second borehole in Jura Ost will be Bözberg-2. In the Zürich Nordost siting region, the second deep borehole will be drilled in the community of Marthalen. The drill site was completed in autumn 2019 and drilling began in early February 2020.

In the Nördlich Lägern siting region, Nagra will conduct its second deep borehole, Stadel-3, in the area of Hasliboden. Some tests that could not be conducted in Bülach can be performed in Stadel. The start of drill site construction is expected for spring 2020.

Obtaining an overall picture

It is still too early to say which site is best suited for a repository. New data keep coming from ongoing borehole investigations, as well as from laboratory analyses and interpretations, and boreholes have not yet been drilled in every siting region.

The different field investigations and studies conducted by Nagra and its partners deliver factual input that will be assembled into an overall picture over the next two years. This will be followed by a final comparison of the remaining siting regions.

“THE DEEP BOREHOLES ARE MAKING GOOD PROGRESS.”

Patrick Senn, Division Head Planning & Construction of Deep Geological Repositories



What is your conclusion regarding the deep boreholes drilled in 2019?

“Preparing for the deep boreholes required extensive planning. Finding the right contracting partners for the deep borehole campaign was very time-consuming. The first priority in 2019 was to get the machinery up and running as it consists of many individual components, to eliminate “teething troubles” and to establish a smooth collaboration process. Meanwhile, the Bülach borehole is already history, and in Trüllikon we have drilled through

the containment-providing rock zone. We have begun drilling in Marthalen, and the first drill site in Bözberg has been constructed. It is a great feeling to see the drilling proceeding smoothly now. Although we are slightly behind schedule, the costs and efforts are now under control. Our optimisation of the drilling techniques was successful. It also looks promising for the upcoming boreholes: in 2019 alone, DETEC granted 14 of our deep borehole applications.”

How do you interpret the results?

“So far, observations from the deep boreholes in Bülach and Trüllikon have confirmed our expectations. The measurement results and the hundreds of metres of drill cores are of consistently high quality. The drill cores themselves require a considerable logistical effort: samples are sent directly from the drill site to universities for analysis. The cores are also continuously transported to the temporary core storage facility in Würenlingen. Experts examine them in detail there and take additional samples. The drill cores are also sawed apart and enclosed in resin in preparation for emplacement in our core storage facility in Mellingen.”

What else is important to you?

“I am very pleased that, so far, there have been no incidents worth mentioning and that the drilling has proceeded without any accidents. This is not something that can be taken for granted with a project of this size, and we are doing everything we can for this to remain so. At this point, I would also like to thank the local residents living in the vicinity of the drill sites for their understanding and tolerance. We are aware that drilling causes emissions and we do our best to keep these as low as possible. I am also pleased that our visitors’ pavilions and observation platforms at the drill sites are so popular with the public.”

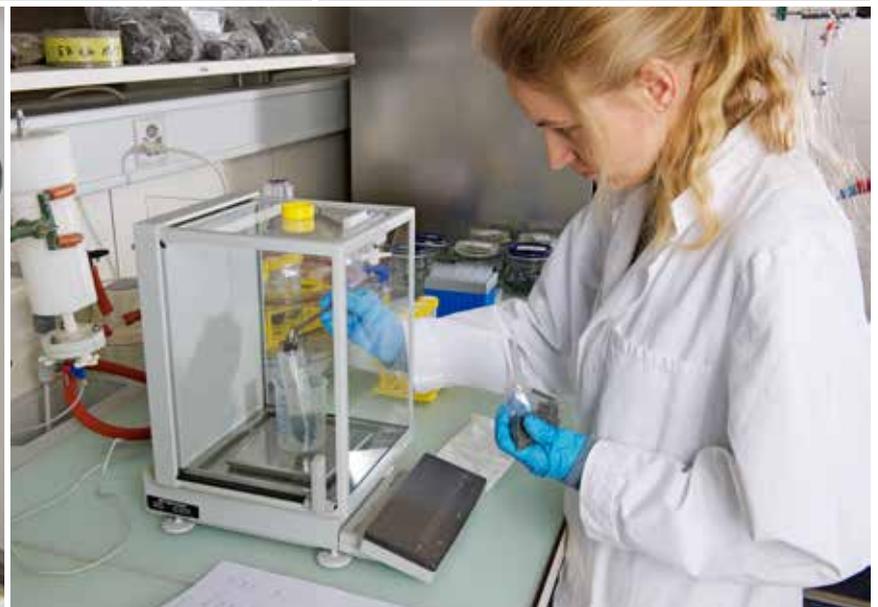
Read more about the deep borehole campaign in our blog: www.nagra-blog.ch



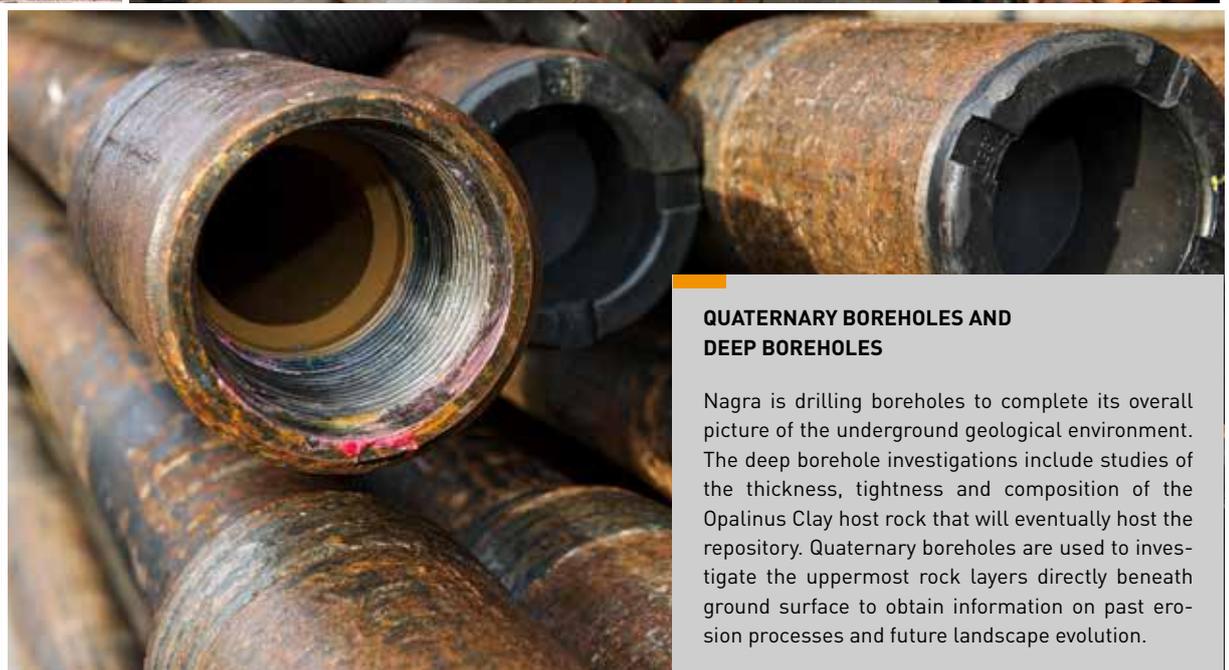
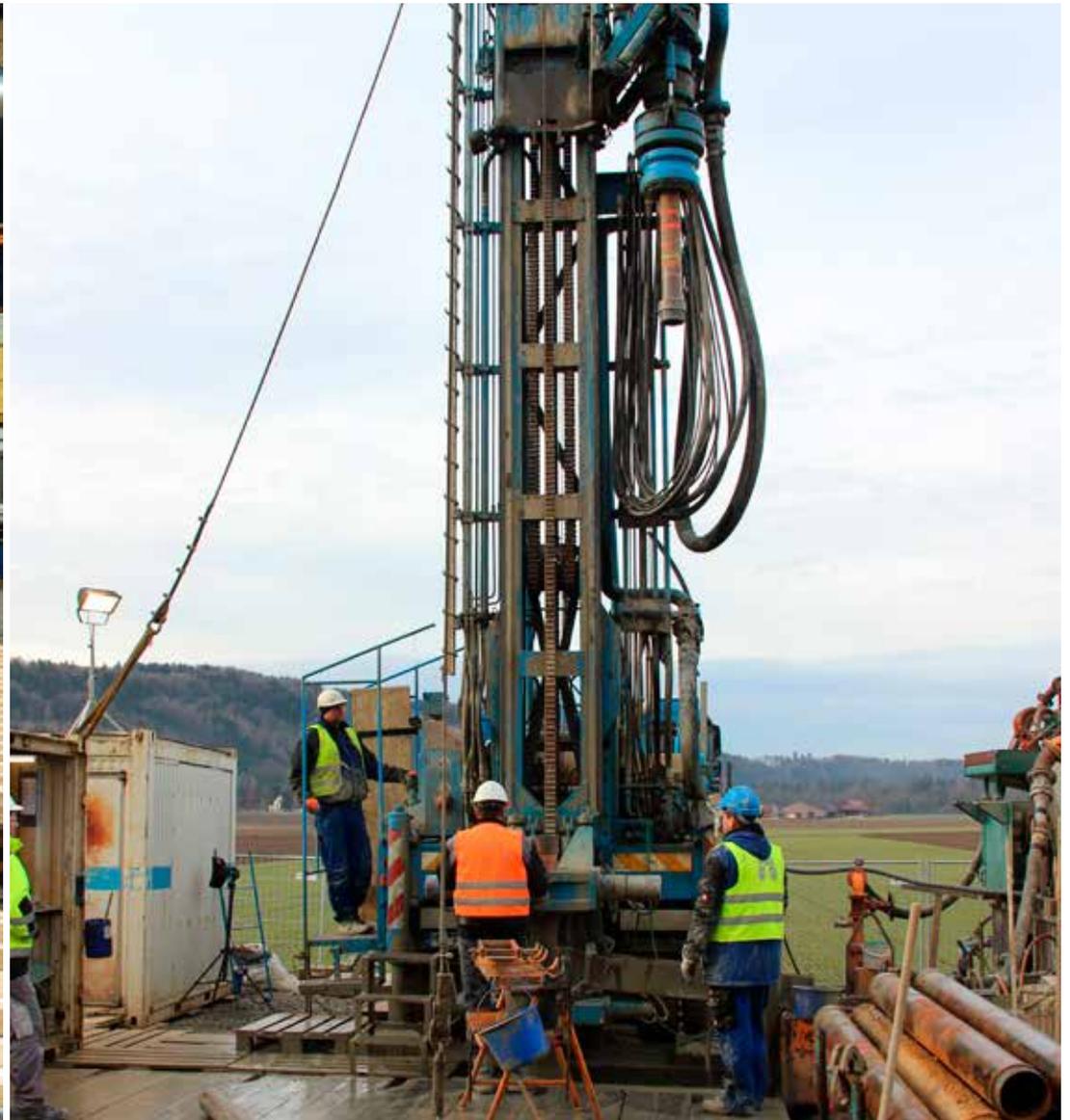
DRILL CORES REVEAL EARTH'S GEOLOGICAL HISTORY

Researchers from the Institute of Geological Sciences of the University of Bern analyse rock samples from Nagra's boreholes. Drill cores are examined, for example, to determine the composition of the porewater contained in the Opalinus Clay. These analyses allow conclusions to be drawn on processes involving the porewater and the substances dissolved in it: e.g. transport processes or the retention of radioactive particles in the Opalinus Clay.

The drill cores from the Quaternary boreholes will first be examined physically. Then they will be cut open lengthwise and digitalised using a high-resolution scanner. The geologists can learn more about the origin of the unconsolidated rocks from the various sediment layers. By applying different dating methods, they can also determine when events such as glacial advances took place.







QUATERNARY BOREHOLES AND DEEP BOREHOLES

Nagra is drilling boreholes to complete its overall picture of the underground geological environment. The deep borehole investigations include studies of the thickness, tightness and composition of the Opalinus Clay host rock that will eventually host the repository. Quaternary boreholes are used to investigate the uppermost rock layers directly beneath ground surface to obtain information on past erosion processes and future landscape evolution.

Quaternary boreholes – a glimpse into the past and the future

Ten out of eleven Quaternary boreholes have been completed. In 2019, these were in Neuhausen, Trüllikon-Rudolfingen, Hochfelden-Strassberg and Kleinandelfingen-Laubhau. The Andelfingen-Niederfeld borehole was begun at the end of November 2019, and drilling continued until the beginning of April 2020. The last borehole in Adikon-Dätwil is planned to begin in the spring of 2020. At a depth expected to exceed 300 metres, it will be the deepest and thus most challenging borehole.

Quaternary borehole investigations focus on sediments located directly beneath the surface, so-called unconsolidated rocks. These date from the Quaternary Period which began around 2.6 million years ago and continues to the present, making it the most recent geological period. The aim is to understand the evolution of the landscape over the last approximately two million years and to predict its future evolution with the purpose of evaluating how well a deep geological repository will be protected against the removal of rock formations (erosion).

Focus on Aare and Thur Valleys

To study past landscape evolution, Nagra aims to learn more about the properties of the unconsolidated rock layers. These can mainly be found in the



“Drill cores from Quaternary boreholes deliver reliable geological information, even in cases where seismic measurements or rock fragments obtained from destructive drilling did not deliver clear results.”

Gaudenz Deplazes
Project Manager Geology

area of present-day river courses which often follow troughs that were once formed by glaciers and re-filled again later. The work focuses on the lower Aare Valley, the “Riniker Feld” and the Thur Valley.

Until now, only destructive drilling has been performed in these areas and analyses have thus been restricted to rock fragments. Nagra’s Quaternary boreholes, by contrast, are fully cored boreholes, i.e. both the layer of unconsolidated rock as well as the first ten metres of the underlying rock formation are brought together to the surface as drill cores. These cores can then be analysed. By the end of 2020, around 1800 metres of drill cores will have been recovered. These will help to find answers to questions such as: How deep did a glacier or river cut into the underground? Do the deposits originate from a lake or a river? How often did a glacier deposit material and where does it come from?

Work in 2019

In 2019, Nagra continued drilling Quaternary boreholes. The first step consists of an in-situ determination of the boundary between the unconsolidated rocks and solid rock, i.e. the location of the so-called bedrock surface. If its location at various positions within the investigated area is known, it is possible to develop a spatial model of the bedrock surface and also to calculate how thick the layer of unconsolidated rock is.

In a second step, drill cores are further analysed and characterised in the laboratory by experts from the University of Bern: What sediments are found in the troughs, what are the grain sizes, and were they deposited by rivers, lakes or glaciers? These data are input into reports that Nagra prepares for each of the Quaternary boreholes. In 2019, five such reports were completed. In a third step, additional analyses of the drill cores are conducted along with an attempt to date the sediments, i.e. to determine their age, using different methods. Dating the drill cores is extremely complex and will continue for some time.

Informative borehole in Hochfelden-Strassberg

The first five Quaternary boreholes reached a depth of a few dozen metres. At the end of April 2019, the first deeper Quaternary borehole was started in Hochfelden-Strassberg. After four and a half months, it was completed at a depth of 278 metres. The bedrock lay 57 metres deeper than predicted. The reasons for this are two-fold. The prediction was based on 2D seismic data that did not allow for a clear geological interpretation of the deeper part of the trough where the drilling took place. In addition, an earlier, less accurate destructive borehole was used to estimate the bedrock surface. Experience with information from such boreholes has shown that determining the boundary between unconsolidated rocks and solid rock based only on rock fragments can be prone to error, especially when rock and sediments are very similar. As a result of the more complex Quaternary boreholes conducted by Nagra in 2018 and 2019, it was possible to continuously recover drill cores, thus enabling the precise determination of the bedrock surface.



Opened orange tube containing a drill core of unconsolidated rock from one of Nagra's Quaternary boreholes.

It is relatively easy to obtain drill cores from solid rock. This is the case with deep boreholes but not with Quaternary boreholes: in unconsolidated rocks, it is a challenge to obtain high-quality drill cores over the entire length of the borehole – especially at depths exceeding 200 metres and where the sediment type changes frequently.

Measurements in the lower Aare Valley

In 2016 and 2017, Nagra conducted 2D reflection seismic measurements in the Nördlich Lägern and Zürich Nordost siting regions to obtain profiles of the troughs. As a result, the Quaternary boreholes could be drilled as close as possible to the deepest point of the trough. In the lower Aare Valley, such measurements were not possible for technical reasons. At the end of 2019, Nagra used an alternative measurement method, i.e. surface wave seismics. This mainly draws on natural underground noise and does not require vibration vehicles. During test measurements at a few points across the trough, it was possible to use this technique to successfully determine a rough profile of the bedrock surface. Subsequently, further profiles were recorded in the lower Aare Valley. Surface wave seismics provides less detailed information than classic 2D reflection seismics but is functional, less complex and thus more economical.



“The Hochfelden-Strassberg borehole was complex and time-intensive, but we also gained a lot of practical experience and obtained very good drill cores.”

Herfried Madritsch
Project Manager Geology

Detailed analyses of 2D seismics, supplementary investigations of unconsolidated rocks surrounding the troughs and existing studies are documented in Nagra reports. The model of the bedrock surface is of particular significance.

Long-term safety of a deep geological repository: investigating erosion

Deep geological repositories must ensure safety over a period of up to one million years during which radioactive waste is hazardous. Safety depends on the protective rock formations deep underground that confine the waste. It is important that this protective function is not threatened due to erosion, i.e. the wearing away of the upper rock layers.

Thickness of the remaining rock is decisive

Nagra has to compare the potential siting regions for a repository with one another with regard to future erosion. For this purpose, it observes different erosion processes such as the incision of rivers and glaciers into the underground as well as the erosion of hills as a result of e.g. slope movements. These processes must not compromise the performance of the clay-based rock layers that, as geological barriers, confine the waste. To achieve this, the rock layer between the repository and the surface has to remain sufficiently thick and provide the required protection even hundreds of thousands of years into the future. Geologists call this the repository overburden.

“A rock layer is needed between the repository and the surface that remains sufficiently thick and provides the required protection.”

To evaluate how the thickness of the overburden evolves over time and how erosion impacts the long-term safety of a repository, Nagra develops scenarios on future erosion. These include studies of the rate at which erosion advanced in the past and identifying relevant erosion processes. Different computer models were used to develop the scenarios, e.g. for climate evolution and the incision of rivers.

Determining the residual cover

In 2019, Nagra conducted field investigations, laboratory studies and computer modelling. In particular, it studied the residual rock cover with regard to decompaction effects. When rock is eroded, the load on the underlying rock formations decreases. As a result, these rock formations can expand, lead-

ing to so-called “decompaction effects” such as higher permeability for water and thus also for radioactive substances. The goal is to estimate how much residual cover remains in place for all three siting regions to ensure that the containment properties of the geological safety barriers are unaffected.

Step 1: Incision of rivers

For each siting region, computer models were used to estimate how deep rivers will cut into the underground over the course of one million years and how much residual cover will remain thereafter. Different scenarios were used for the evolution of the river system along the upper Rhine. One scenario, for example, was the drainage of the Aare River into the Rhone River instead of into the Rhine. The models included data on the continuing uplift of parts of Northern Switzerland, on the lowering of the upper Rhine Graben and on the varying resistance of certain rock types to erosion (so-called erodibility). Global data for comparable rivers as well as data from ongoing investigations on dating sediments in former river courses were also considered.

The erodibility of important rock types found in Northern Switzerland is currently being determined at the German Research Centre for Geosciences in Potsdam. Nagra uses different methods to obtain information on the extent of uplift to date, which include dating rock samples, e.g. ancient river and lake deposits, or moraines. Satellites are also used to determine changes in the height of the earth's surface.

Step 2:**Area-wide erosion of the landscape surface**

In a second step, the area-wide erosion of the local landscape (topography) due to slope movements was investigated. When a river cuts into the underground, this can lead to changes such as slope movements within the river's catchment area. How much a slope moves depends on its degree of inclination and on how hard the rocks are that it consists of.

In a newly initiated pilot project, Nagra aims to use modelling and so-called sensitivity studies to determine which parameters influence erosion of the local topography most strongly.

Initial results show different residual covers for each of the three siting regions after one million years. It is, however, still too early for final conclusions.

The climate influences rivers and glaciers

Erosion by rivers and glaciers is influenced by climate evolution. Using climate models, the past can be reconstructed and indications of future climate evolution can be obtained. Nagra is working with the Potsdam Institute for Climate Research (PIK) and the Oeschger Centre of the University of Bern to develop climate modelling studies.

Systematically benefiting from expert know-how

In 2019, Nagra held several workshops and structured elicitation with scientific experts in the area of long-term geological evolution, where they could exchange their latest specialised knowledge and discuss their respective opinions. These structured elicitation also helped to reduce uncertainties in the parameters and models. In the future, further expert workshops will be conducted on selected erosion-related questions.

Ice flow modelling: Erosion by glaciers

In collaboration with the ETH Zürich, the University of Zürich and the New Mexico Technical University, Nagra is developing computer models that illustrate the evolution of glaciers over the last 100 000 years. Nagra is particularly interested in the evolution of glaciers that could influence the geologi-

cal siting regions. Building on this, scenarios are developed that allow Nagra to assess future glacial erosion in the siting regions for a deep geological repository.

The properties of the ice can be determined using computer models, and entire glacial cycles with advance and retreat can be simulated. Such ice flow models can show, for example, how far alpine glaciers advanced into the Swiss Plateau during the most recent ice age.

MODELLING STUDIES AND FIELD INVESTIGATIONS ON GLACIERS

Urs Fischer, Project Manager Safety Analyses and expert on glaciers



"Together with the ETH, we are working on projects on glacial erosion. Ice flow models help us to better understand the processes involved. We are also conducting additional research on current glaciers. As part of an international research team, I went to Greenland a while ago where we investigated hydrological and hydrogeological processes associated with ice-age glaciation and the formation of permafrost. We also wanted to find out how glaciers function and what their impact on future glaciation will be."



Undergoing testing: In December 2019, Nagra conducted drop tests with concrete containers that will be used for the transport and storage of low- and intermediate-level waste.

Optimising disposal canisters

Drop test on concrete waste containers

In December 2019, Nagra conducted drop tests on concrete containers in Pieterlen (Canton Bern). These are used for transporting and storing low- and intermediate-level waste. As the waste containers are transported on public roads, national and international norms and regulations apply to their design. Nagra has to demonstrate that these are being complied with and therefore commissioned a testing institute to conduct drop tests and additional experiments and calculations.

For the drop tests, containers weighing between 15 and 25 tonnes are dropped onto a steel plate. They have to withstand the drop without losing their contents or impairing the radiation-shielding impact of the concrete. To obtain a realistic weight, the containers were filled with steel components or concrete fragments such as typically arise during the dismantling of nuclear power plants, and then backfilled with mortar. Non-radioactive material was used for the tests.

After detailed analyses of the tests, Nagra received the results from the testing institute in late February 2020. The signs are good that the required demonstration can be provided and that the containers are suitable for transport in line with legal stipulations.

Consortium investigates metal corrosion

In 2017, together with waste management organisations from Canada (NWMO) and Belgium (Ondraf/Niras), Nagra established the Nuclear Waste Consortium on Corrosion. Its purpose is to exchange know-how and co-fund research work on corrosion of metals and the generation of gas. These are chemical processes that occur in a sealed repository for radioactive waste and are relevant for safety.

Measurements in Canada

The work on corrosion is being conducted at Canmet Materials, a large research centre in Canada. With the equipment and expertise available there, it is possible to accurately measure extremely low corrosion rates. A low corrosion rate means that metals corrode very slowly. This is the case with copper-coated disposal canisters for spent fuel assemblies and high-level waste, or in a repository for low- and intermediate-level waste where large amounts of cement are used: there, carbon steel corrodes at a very slow rate.

Extremely slow corrosion is measurable

The work carried out in 2019 has shown that the anaerobic corrosion rate of steel in cement is below one nanometre per year. This could not have been measured using previously available techniques. In addition, development began of a novel hydrogen sensor that will allow automated corrosion rate measurements.

CONCRETE CONTAINERS AS PACKAGING

In its disposal concept, Nagra plans to use two concrete container types of different sizes (LC-84 and LC-86) for raw wastes such as contaminated or lightly activated steel beams or pipes resulting from the dismantling of the nuclear power plants. Steel drums with processed waste arising from the operation of the nuclear power plants or in the fields of medicine, industry and research can also be packaged in these containers in a form suitable for final disposal. Concrete containers with radioactive waste are transported from the nuclear power plants to the interim storage facility. Additional containers will be filled at the interim storage facility. When the deep geological repository finally becomes operational, the filled containers will be transported there and disposed of permanently.

Grimsel Test Site

At Nagra's Grimsel Test Site (Canton Bern), research on the deep geological disposal of radioactive waste has been ongoing for 35 years. 450 metres beneath the surface, ideal conditions prevail for investigating the performance of the geological and engineered safety barriers of repositories. The research results are directly incorporated into exploration programmes of the underground, modelling studies, safety reports and studies on the realisation of repositories.

At the Grimsel Test Site, an active exchange of knowledge is conducted with the international project partners on a wide range of topics relating to repository research and on the results of ongoing experiments. This is also the case at the annual meeting of the International Steering Committee of the Grimsel Test Site, the "ISCO" meeting.

Tests on tunnel seals

At the Grimsel Test Site, investigations include the sealing of tunnels of a deep geological repository for low- and intermediate-level waste as part of an important full-scale experiment called the "Gas-permeable Seal Test – GAST". This aims to demonstrate the functionality of a gas-permeable tunnel seal that contributes to the removal of gas from a repository. This engineered barrier can remove gas and, at the same time, retain the radioactive substances dissolved in water. The gas is generated by the degradation of organic radioactive waste and by the corrosion of metals under anaerobic conditions. Under very unfavourable conditions, excessive gas pressure could impair the safety barriers and thus also the integrity of the repository. For this reason, the experiment makes an important contribution to ensuring the safety-oriented sealing of a future repository.

Work conducted in 2019

The tunnel sealing project is currently in its final phase, with the focus on implementing and evaluating the final gas transport test planned for 2022. In 2019, preparatory work was carried out in three areas: a) homogenisation of water saturation and water pressure in the tunnel seal to be tested; b) analysis of a gas pre-test to describe current gas transport pathways; c) development and construc-

tion of a test cell for the accompanying laboratory investigations.

The analysis of the gas pre-test has already confirmed important properties of the gas-permeable tunnel seal. The insight gained from this pre-test could also be used for the final project planning: in 2020, a numerical planning and analysis tool for the gas transport test will be developed. Initial results of the accompanying laboratory investigations are also expected for this year and will be used to calibrate the tool.

MAIN EXPERIMENTS AT THE GRIMSEL TEST SITE

CFM Formation and migration of colloids and their influence on the mobility of radionuclides

CFM i-BET In-situ bentonite erosion test

CIM Testing the transport properties of C-14 and I-129 through cement barriers

GAST Gas-permeable seal test: gas-permeable tunnel seal for a L/ILW repository under realistic conditions and on a realistic scale

HotBENT Investigation of the safety function of bentonite barriers exposed to elevated temperatures

ISC Controlled hydraulic stimulation of existing fault zones; experiment run by the Swiss Competence Center for Energy Research – Supply of Electricity

LASMO Monitoring and characterisation of the geosphere

LTD Long-term diffusion of radionuclides

MaCoTe Corrosion experiments with components of the engineered barriers

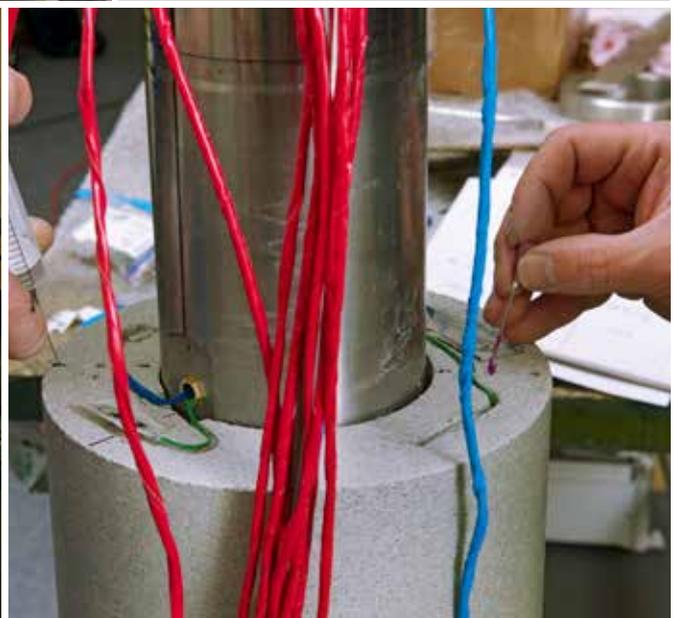
Plug experiment Engineering studies and demonstration experiments on repository design



ANNIVERSARY OF THE GRIMSEL TEST SITE

2019 marked the 35-year anniversary of the Grimsel Test Site. Over 20 organisations from 12 countries, including the EU, are currently conducting research here. It is the only underground laboratory worldwide where researchers can carry out experiments under controlled conditions, for example on the behaviour of radionuclides in fractured rock. Under realistic conditions, traces of radioactive substances are used to investigate their slow migration through small fissures and fractures in the rock or their retention.

Additional experiments contribute to the development and refinement of safe waste disposal concepts as well as to the characterisation of granite. In some countries such as Sweden, granite is the host rock for a deep geological repository.



Mont Terri Rock Laboratory

Expansion of underground rock laboratory completed

In 2019, the expansion of the Mont Terri Rock Laboratory with Gallery 18 was completed on schedule. The breakthrough took place in May 2019. The new gallery has been available for experiments since early 2020.

Testing lining methods for emplacement drifts

Nagra used the expansion work for its TS Experiment ("Testing different tunnelling support in sandy facies") and tested lining methods for supporting and securing excavated drifts in the Opalinus Clay. Tunnel sections were selected and supported with steel arches or shotcrete. In these sections, the impact of overburden pressure was observed in the form of the resulting deformations. The experiment provides information on the rock and system behaviour between the lining and the rock during tunnel excavation in the Opalinus Clay.

Fibre-optic cables measure deformations

In the TS Experiment, deformations of the tunnel cross-section were observed using both the classic optical measurement method as well as fibre-optic cables installed in 2018. These light conductors are sensitive to expansion and could successfully measure the deformations of the lining. In 2019, the measurement results from each of the differently supported tunnel sections were evaluated and compared with one another. The researchers were able to track where deformations occur for each of the lining methods and how extensive they are. The rock and system behaviour did not yield any great surprises as everything reacted as expected. In addition, it was possible to demonstrate that the rock can be reliably supported using steel arches. However, further long-term measurements are required to show whether weathering processes in the Opalinus Clay lead to an impairment of the support using steel arches.



The experiment investigating microbial activity is conducted in an oxygen-free environment. The bioreactors are located in the grey "glove box" in a nitrogen atmosphere.

Lining tunnels with concrete elements

Aside from steel arches and shotcrete, Nagra experimented with an additional tunnel support method in 2019, namely lining segments. These pre-fabricated concrete elements are often used during tunnel construction. A tunnel-boring machine excavates the rock and continuously installs the segments. This method would have a number of advantages compared to others, especially with regard to occupational safety during excavation.

Microbial activity experiment: investigating the consumption of hydrogen

Gas will be generated in a deep geological repository. It will consist primarily of hydrogen resulting from the corrosion of metals under anaerobic conditions. To ensure that the radioactive substances remain safely enclosed, the gas pressure should not become too high. Experiments conducted at the Mont Terri Rock Laboratory show that different bacteria can be found in the Opalinus Clay. They consume hydrogen and influence the corrosion of metals as well as the transport of radioactive substances. The conditions in a repository can be set up so that bacteria present in the construction and operations tunnels remain active over a long time period during which they consume hydrogen.

Searching for clues with the help of bioreactors

In 2019, Nagra and the Environmental Microbiology Laboratory at the EPFL investigated the growth and activity of a wide range of hydrogen-consuming bacteria at the rock laboratory. Several bioreactors were used to simulate the bentonite safety barrier in a backfilled operations tunnel of a repository. Synthetic porewater that had previously been in contact with the Opalinus Clay was passed through the reactors to dissolve the bacteria and bring these to the reactor. Hydrogen was supplied to the middle of the reactor as “food” for the bacteria. After several months, samples were taken from the bioreactors to analyse the bacteria genetically. Among hydrogen-consuming types of bacteria, there are so-called “sulphate-reducing bacteria” and bacteria that generate methane gas. Until now these had been assumed not to be simultaneously active, but, with the help of the bioreactors, it could be demon-

strated that this is the case after all. It is also known now which bacteria are active at which location in the bioreactor and what conditions prevail there.

KEY EXPERIMENTS IN THE MONT TERRI ROCK LABORATORY

- CI** Mineralogical interaction between claystone and cement
- CI-D** Diffusion across the concrete/claystone interface
- DF** Drilling fluids for Opalinus Clay
- DR-A** Diffusion and retention of radionuclides
- DR-B** Long-term diffusion experiment
- FE-M** 1:1 emplacement experiment for investigating the near-tunnel environment (FE) with sub-projects on gas evolution (FE-G) and monitoring
- FS-A** Laboratory investigations of hydromechanical properties of tectonically reactivated Opalinus Clay
- FS-C** Imaging the long-term integrity loss of disturbed host rock zones
- GC-A** In-situ rock-mechanical characterisation of Opalinus Clay
- GD** Analyses of geochemical data
- HA-A** Variability of the hydraulic and geophysical properties of the Opalinus Clay
- HE-E** Behaviour of the engineered barriers under the influence of heat
- IC-A** Corrosion behaviour of various types of metal in bentonite
- MA** Investigation of microbial reactions
- MA-A** Microbial processes in the bentonite barrier
- SO-C** Facies analysis of the upper Opalinus Clay and the transition to the Passwang Formation
- TS** Testing possibilities for tunnel support in sandy facies

International Services and Projects (ISP)

Experienced scientists as well as a competent pool of external experts ensure the continuous growth of Nagra's know-how. In 2019, the worldwide collaboration with partners and organisations was continued and expanded – extending from Switzerland via Europe all the way to North America and Asia.

One of the year's highlights was the introduction and application of Nagra's Advanced Methodology for Activation Characterisation (AMAC) in connection with the decommissioning of nuclear installations in South Korea. With this method, it is possible to determine the distribution of radioactivity in a decommissioned nuclear power plant. It has already been applied successfully in Switzerland's nuclear power plants and during the decommissioning of the research reactor at the University of Basel, as well as in Germany. Representatives of other waste management organisations also applaud this state-of-the-art approach and regard the method as a key factor in efficiently planning decommissioning and optimising waste packaging.

Numerous workshops held ...

In 2019, Nagra continued the collaboration and know-how exchange with its partners in the form of workshops, training courses and special studies. In January, a three-day workshop was held with RWM, Nagra's sister organisation in the UK. The focus was on the hydrogeology and hydrochemistry of low permeability rocks as well as on the characterisation and description of groundwater movement in these rocks. At the end of 2018, the UK resumed its search for a repository site, and it will conduct explorations similar to those that Nagra has been carrying out in the siting regions since 2015. For this reason, RWM was very interested in the experiences of Nagra's staff and research partners who were, and still are, involved in such investigations.

... also at the Grimsel Test Site

In June, two workshops were conducted within the framework of the "Grimsel Training Centre". The first was a tailor-made course for Nagra's South Korean partner, KORAD, with the focus on the role of bentonite in radioactive waste disposal. The second workshop was open to a wider audience and focused on the development of geological models from geophysical field data. The course addressed topics such as seismic interpretation, data processing, 3D exploration and data acquisition as well as uncertainty analysis and tomography. Participants were able to attempt a first interpretation of real data from Nagra's most recent seismic campaigns. Experienced Nagra staff provided support as well as detailed information on the challenges involved in planning and implementing seismic campaigns.

Gaining practical experience at the Test Site

In September 2019, a six-day course was conducted on different experiments performed directly in the rock (so-called in-situ tests) and the hydraulic characterisation of rocks. As part of the course, the participants could gather theoretical knowledge as well as practical hands-on experience.

INTERNATIONAL SERVICES AND PROJECTS (ISP)

Nagra's ISP Division is responsible for projects with funding sources outside the Swiss national programme, as well as for the Grimsel Test Site. The activities cover a wider spectrum of projects: strategic programme planning, specification of waste inventories, site selection, site characterisation and evaluation, repository conceptual design, safety case development and safety analyses, public outreach, training and know-how build-up.



Top: At present, over 20 partner organisations from different countries participate in the experiments at the Grimsel Test Site. Every year, representatives of the partner organisations gather at the “International Steering Committee” (ISCO) Meeting. 2019 marked the 35-year anniversary of the Test Site.
Bottom: After concluding the formal exchange, participants of the ISCO Meeting visited the Aare Gorge.

International collaboration

Start of new European programme EURAD

EURAD, the “European Joint Programme on Radioactive Waste Management”, started on 1st June 2019. A total of 51 organisations from 23 countries are directly involved in the research programme. The overall budget for the first five-year test phase is EUR 60 million. Nagra and the Paul Scherrer Institute (PSI) are key members of EURAD. The University of Bern, the EPFL and the ZHAW support Nagra in their work and thus also participate in the programme. Nagra is involved in four work packages on research, development and demonstration (RD&D) and in a network for knowledge transfer. It also participates in an active information exchange on strategies and tools for handling uncertainties in connection with the waste management programmes.

International knowledge transfer

Nagra benefits from the know-how and new insights of other participants in the programme, thus placing itself at the front line of research on internationally relevant topics. In addition, due to the EU's financial support, Nagra does not have to finance all of the work itself.



“Nagra plays an active part in many international research projects and shares its expertise with other organisations.”

Irina Gaus
Head of Research & Development

Targeted research work

Research focuses on the impact of the corrosion of steel disposal canisters on the bentonite tunnel backfill and its associated effects on long-term waste containment. Together with the University of Bern, Nagra is investigating how corroded iron interacts with smectite, which is a swelling clay mineral and one of the main components of bentonite. The experimental set-up was developed in 2019.

Research also includes gas transport in clay-based materials used as an engineered barrier (bentonite) and as a geological barrier (Opalinus Clay) of a repository. An excessively high gas pressure can impact the safety function of the geological barrier. Analyses focus on processes associated with water and gas that can affect the clay-based barrier, and on processes through which the Opalinus Clay geological barrier seals itself again. In 2019, the first samples of Opalinus Clay and Nagra's measurement data from the Mont Terri Rock Laboratory were sent to the EURAD partners for laboratory experiments and modelling studies.

Investigating the impact of heat and characterising fuel assemblies

Investigations include the impact of heat on clay-based materials in a repository for high-level waste, because if the heat produced by the waste becomes too high, this threatens the capability of the clay-based materials to contain the waste. For its research partners, Nagra prepared comprehensive measurement data from the Full-scale Emplacement (FE) Experiment documenting the impact of temperature. The first drill cores from the ongoing deep borehole campaign were also prepared for laboratory investigations.

Additional research focuses on characterising spent fuel assemblies. Nagra is interested in mechanisms that influence the behaviour of the spent fuel assemblies over an extended interim storage period. If the spent fuel or its cladding is impaired, this negatively influences its mechanical strength. Nagra is an international leader in the field of characterising spent fuel assemblies and their behaviour. In 2019, under Nagra's lead, the project partners began compiling the current state of the art in science and technology in a project report.

Switzerland presides over technology platform

The technology platform “Implementing Geological Disposal of Radioactive Waste Technology Platform” (IGD-TP) coordinates activities on the planning and realisation of deep geological repositories in Europe. In early 2019, Nagra took over the secre-

tariat for two years, and Irina Gaus, Nagra's Head of Research & Development, is chair. In October, the members celebrated the 10-year anniversary of the platform in Finland with a visit to the first deep geological repository for high-level waste worldwide, which will go into operation in 2025. To represent the interests of the involved waste management organisations, IGD-TP also joined the EU programme EURAD and helps to shape its programme management.

Workshop on climate evolution and a project on bentonite

In June, Nagra conducted a workshop on climate evolution and potential consequences for the safety of a deep geological repository. The topics discussed included methods for recording climate change and solutions for a more intensive collaboration of waste management organisations.

The "Kiruna Natural Analogue" project was started in September. Nagra is a project partner and is involved in the investigations on the long-term behaviour of bentonite under repository-relevant conditions that are being conducted in an iron ore mine in Northern Sweden.



Representatives from 12 European waste management and other organisations manage the IGD-TP and celebrated the platform's 10-year anniversary in Finland.



On 15th April 2019, Nagra held a media event on the occasion of the start of the deep borehole campaign in Bülach. This met with huge interest on the part of media representatives from the areas of print, electronic media, radio and TV. In the days that followed, 150 articles were published on the start of the first borehole.

Public outreach

Remake of virtual “Journey through time”

The “Journey through time to a deep repository” uses a very realistic approach to 3D animation to show how waste is transported, packaged and emplaced deep underground. The animations were reworked using the so-called motion capture process. Better rendering techniques and higher-resolution glasses provide visitors to the exhibitions with an even more realistic experience. A new exhibit on deep boreholes uses an iPad and augmented-reality technique to let visitors explore a drill site. It also provides information on the Opalinus Clay and other rock formations that are being investigated in more detail as part of the deep borehole campaign.

Nagra visited 13 regional trade fairs and a TecDay that took place at a cantonal school with its “Journey through time” exhibit. At three local markets, it was present with a booth where visitors were invited to take a hammer to fragments of fossil-rich Posidonia Shale under the guidance of a staff member. Last year, it also supported the exhibitions at the visitor centres of the nuclear power plants: it helped to design a new exhibit for the utility BKW Energie AG on the dismantling of the Mühleberg nuclear power plant and organised an event at the Leibstadt nuclear power plant in June 2019.

Experiencing science in underground rock laboratories

At the Grimsel Test Site (BE) and Mont Terri Rock Laboratory (JU), experiments on radioactive waste disposal are conducted under realistic conditions and guided tours are very popular with visitor groups. During 2019, 1185 people visited the Grimsel Test Site and 4585 people toured the Mont Terri Rock Laboratory. Special open days were held for interested residents of the Jura Ost, Nördlich Lägern and Zürich Nordost siting regions and for over 300 land owners and tenants affected by the past seismic campaigns. Overall, three open days were held at the Mont Terri Rock Laboratory and five more at the Grimsel Test Site.

Films illustrating Nagra topics

In 2019, Nagra produced four films that were published on its YouTube channel. Two explanatory films provide answers to frequently asked questions: How did Nagra identify the potential siting regions for a deep geological repository? And why is the Opalinus Clay best suited for hosting a repository? In 2019, an intern shot two “teaser films” for Nagra. In the video titled “Visiting a drill site”, geology student Stella Braunschweig visits the information centre at the Bülach drill site and learns exciting facts about deep boreholes. The other film provides an impression of what interested individuals can experience when visiting a Nagra exhibition stand. Nagra apprentice Aleksander Timotijevic had a look around his employer’s stand at the Untersiggenthal trade fair and shared his impressions in the film.

Nagra’s latest films are available on its YouTube channel:



Electronic media

The section “Disposal where” on Nagra’s website (www.nagra.ch) was revised and a new page on “surface infrastructure” was added to the info corner. The web pages on the individual drill sites are continuously updated with the latest information. In the Nagra blog (www.nagra-blog.ch), the deep boreholes are documented in numerous articles as well as in photos and videos. At the end of January, Nagra sent out an “e-info” newsletter to around 2000 subscribers and two newsletters for teachers were sent to around 250 subscribers.

Print products

Nagra produced a brochure on the surface infrastructure for a deep geological repository along with factsheets with explanations for each of the regions. A factsheet was also published on encapsulation plants for radioactive waste outside the siting region for a deep geological repository. A flyer on borehole seismics provided information to landowners and tenants. The last paper issue of "Nagra info" was published in January 2019. In the future, this will appear as an electronic newsletter.

Nagra's information trips

Nagra informs the wider public about topics relating to radioactive waste disposal. Its information concept is presented in the Waste Management Programme that has been approved by the Federal Council. As part of this obligation to provide information, fact-finding trips have been organised to waste management facilities abroad since the

"The deep borehole campaign clearly dominated Nagra's media coverage in 2019. The media office conducted a total of three information events."

1980s. Members of the Swiss Parliament are invited, as well as members of the regional conferences from the potential siting regions, of the cantonal parliaments and the community authorities from the potential siting regions, as well as associations and other interested parties.

Participants are given the opportunity to visit existing waste disposal facilities in other countries and to share their experiences. Due to the packed programme, participants have no free time at their disposal. Nagra bears the costs of the two- to three-day trips that are also accompanied by one representative of each of the federal authorities (SFOE, ENSI) who provide information and expertise. Nagra conducted two information trips in 2019: 30 people travelled to Sweden and Germany from 8th to 10th August and, on a two-day trip in September, Nagra took 30 people to Germany.

Nagra in the media spotlight

The deep borehole campaign clearly dominated media coverage in 2019. The media office held a total of three events. Two of these took place in Bülach – coinciding with the start and completion of the borehole – as well as the start of drilling operations in Trüllikon. Nagra's first deep borehole in Bülach met with broad national interest. The Swiss TV news programme "Schweiz aktuell" (Switzerland Today), for example, aired a comprehensive report on the process of recovering drill cores from the borehole, extracting samples and then sending them to a laboratory at the University of Bern for further analysis.

The local media in the Nördlich Lägern and Zürich Nordost siting regions reported extensively on the deep boreholes in their regions. In addition, eight media releases provided timely information for the public.

A variety of offers for schools and young people

Maintaining an active dialogue with the young generation is and will remain an important concern of Nagra. Over 900 students worked on the topic of radioactive waste disposal in 2019. Aside from the usual classroom visits and the ever-popular excursions to the underground rock laboratories, classes of students also visited the drill site in Bülach. The offer "workshop at the drill site" was newly created in 2019 and encourages actively addressing the waste disposal issue with the emphasis on dialogue.

Interviews conducted as part of school-leaving and other final apprenticeship exams also focused on the dialogue with young people. Among the school material provided by Nagra, the Philion experiment sets that allow students to conduct their own experiments on radioactivity remain very popular.



Nagra in the classroom: Nagra employee Lukas Oesch in an exchange with pupils from Lucerne at the TecDay held in January 2019.

Voices from the world of politics



Hansjörg Knecht has represented Canton Aargau as a member of the Council of States since early December 2019. Prior to this, the Swiss People's Party member and entrepreneur from Leibstadt had been a member of the National Council from late 2011. Among other responsibilities, he is a member of the Council of States' Environment, Spatial Planning and Energy Committee (ESPEC) that also deals with topics related to radioactive waste disposal.

At the moment, the search for a site for a deep geological repository is ongoing. What is important to you, and what do you see as the responsibility of politicians?

Radioactive waste disposal is a national task and responsibility. It is crucial to select the safest site, and individual interests thus have to be set aside. Where a deep geological repository will eventually be built is not a political but primarily a geological question; it is the job of politicians to present this situation to the public in a credible manner. Transparent and clear communication of the criteria and results of the Sectoral Plan process promote trust and acceptance.

The radioactive waste will eventually be disposed of in deep geological repositories in Switzerland. How can politicians contribute to the success of this project and to public acceptance?

Politicians are responsible for creating suitable boundary conditions in all areas. To achieve this, a constructive collaboration on all levels and an objective, factual communication approach are indispensable. It is essential to minimise negative impacts for the public to the greatest degree possible. The supervision and safety of the repositories have to be ensured at all times, but issues such as traffic increase or drilling noise also require suitable solutions. It is clear that any burdens resulting from a repository have to be compensated with a satisfactory financial settlement.



Beat Walz has been a member of the National Council for Zürich since 2014. The Liberal Democratic Party member and lawyer from Bauma took over as party chairman in 2017. Among other positions, he is a member of the National Council's Economic Affairs and Taxation Committee (EATC-N) and has been following the topic of radioactive waste disposal for years.

At the moment, the search for a site for a deep geological repository is ongoing. What is important to you, and what do you see as the responsibility of politicians?

The basic prerequisite is selecting the safest site. This criterion may not be overridden politically in the decision-making process.

To meet the deadlines foreseen for the site selection process, all participants have to collaborate in a target-oriented manner. Politicians have to comply with the stipulations of the authorities and not provoke any unnecessary delays. It is also important that the region that will eventually host the repository will not suffer any adverse effects.

The radioactive waste will eventually be disposed of in deep geological repositories in Switzerland. How can politicians contribute to the success of this project and to public acceptance?

The entire procedure has to remain goal-oriented, and an important element of this is to involve the siting regions even more. The Liberal Democratic Party has repeatedly and clearly called for this. The siting regions may not be unnecessarily burdened, and their confidence in rapid progress should not be abused. As politicians, our task is to make sure that the affected Cantons, communities and the public are informed in a transparent manner. Particularly when the announcement is made of the site for which the general licence application will be prepared, it is essential for the Federal Government and Nagra to communicate effectively.



Gabriela Suter has represented Canton Aargau on the National Council since early December 2019. The member of the Social Democratic Party of Switzerland (SP) and self-employed historian from Aarau has been president of the SP for Canton Aargau and a member of the national SP's Executive Board since 2018. She is a member of the National Council's Environment, Spatial Planning and Energy Committee (ESPEC-N) that also deals with topics related to radioactive waste.

At the moment, the search for a site for a deep geological repository is ongoing. What is important to you, and what do you see as the responsibility of politicians?

In the site selection process for a nuclear waste repository, the safety of humans and the environment must have the highest priority. A repository has to remain safe over one million years – that is how long the waste emits radiation. This still poses many unresolved questions, for example about the host rock: In the 1970s, Nagra was of the opinion that anhydrite was the most suitable rock, in the 1980s the marl in Wellenberg was considered safe, then it was granite for a while and today it is supposed to be Opalinus Clay... Which rock will be considered next as "the safest"? How can a repository be protected from natural events such as earthquakes for thousands of years? In addition, drilling is presently being con-

ducted in places that have water-bearing rock layers. Contaminating the groundwater flow would be fatal for the drinking-water of millions of people.

Aside from technical safety, procedural safety is also important. The politicians have the task of supporting the process critically to ensure that the best possible solution is found.

The radioactive waste will eventually be disposed of in deep geological repositories in Switzerland. How can politicians contribute to the success of this project and to public acceptance?

Whether we will one day dispose of radioactive waste in a Swiss repository has not been decided yet. To date, we possess neither the long-term experience, nor is there a single operational repository for high-level waste anywhere in the world. Under no circumstances may a deep geological repository be realised too hastily – the German experience at the Asse salt mine serves as an example of that.

The people in the siting communities must have the right to participate in and decide on factual issues – and, as they are directly affected, they should have a veto right. The way the present-day regional conferences are structured does not allow genuine participation, or only within limits. The conferences thus serve more as information events for Nagra and the authorities rather than as critical discussion forums.

It is not a political task to convince the population on a deep geological repository. The question has to be what Nagra can contribute to increase acceptance and trust. It should introduce the principle of public access and create complete transparency.



Martin Bäuml has been a member of the National Council of Zürich since December 2003. He is also a member of the town council of Dübendorf. In 2007, he founded the Green Liberal Party of Switzerland and was its president until 2017. Since then, he has been the party's vice-president. He is a member of the National Council's Environment, Spatial Planning and Energy Committee (ESPEC-N) that also deals with topics related to radioactive waste.

At the moment, the search for a site for a deep geological repository is ongoing. What is important to you, and what do you see as the responsibility of politicians?

One preliminary remark: The Green Liberals do not believe that safe disposal of high-level waste can be guaranteed. Nobody can make a guarantee over several tens of thousands of years. Yet Switzerland is obliged to dispose of the waste resulting from the use of nuclear energy as safely as possible. The Green Liberals believe that a repository with a retrievability option is the best solution and must thus be further pursued. However, the top priority is the safety of the repository, including its surface facilities and transport routes. The supervisory authorities and all of us have to keep a close eye on Nagra so that it does not make false economies and conducts all necessary safety clarifications in an unbiased manner.

The siting regions have to be included even more. The Green Liberals call for the Cantons to also make themselves heard and to voice their concerns at any time. Involving those concerned and thoroughly clarifying all questions will predictably lead to delays, but as this relates to the maximum level of safety and acceptance of the repositories in the siting region, Nagra and the federal authorities have to accept this. Ultimately, a repository can only be realised with public consent.

The radioactive waste will eventually be disposed of in deep geological repositories in Switzerland. How can politicians contribute to the success of this project and to public acceptance?

We politicians have to critically monitor the radioactive waste disposal process and insist on the full resolution of all open questions. One related aspect of great relevance is groundwater and drinking-water protection in the vicinity of the hot cell, where the radioactive waste is transferred from the Castor containers.

Deep geological disposal requires further clarification, and we question whether a combined repository for all waste categories can be safely operated in the long term. Nagra has to demonstrate that it is possible to safely construct such a repository and that the radioactive waste can still be retrieved. To this end, further experiments and verification in pilot repositories are needed.

Aside from resolving fundamental questions on safety, an important issue for the affected population is that settlements and compensation measures are clearly regulated before a general licence for a repository can even be discussed. We politicians have to use our influence to ensure that the procedure is managed in compliance with these rules of play.

Board of Directors



Corina Eichenberger
President of the Board of Directors

Dr. Willibald Kohlpaintner
Vice President
Axpö Power AG

Dr. Philipp Hänggi
BKW Energie AG

Dr. Thomas Kohler
Alpiq AG

Roland Grüter
Kernkraftwerk Leibstadt AG

Dr. Michaël Plaschy
Kernkraftwerk Gösgen-Däniken AG

Ronald Rieck
Zwilag Zwischenlager Würenlingen AG

Dr. Thierry Strässle
Swiss Confederation

Peter Zbinden
Herrliberg (ZH)
former Chief Executive Officer
of AlpTransit Gotthard AG

Board of Directors and annual general meeting

The Board of Directors held four meetings and closed meetings on proposals for the surface infrastructure and the safety-based comparison in 2019. The main focus was on supporting the Sectoral Plan process. The Board of Directors also took note of the planned research and development projects for 2020 and approved a corresponding framework credit. The Technical Committee met four times, and the Commission for Communication and Information held three meetings. The Finance Commission met twice to consider the closing of the annual accounts for 2018, the budget for 2020 and the accumulated accounts. The annual general meeting of the members of the Nagra Cooperative was held in Bern on 25th June 2019. The members approved the annual report and accounts for 2018.

Members of the Cooperative

Swiss Confederation
Bern

Alpiq AG
Olten

Axpo Power AG
Baden

BKW Energie AG
Bern

Kernkraftwerk Gösgen-
Däniken AG
Däniken

Kernkraftwerk Leibstadt AG
Leibstadt

Zwilag Zwischenlager
Würenlingen AG

Technical Committee

Dr. Thomas Kohler
Chairman
Alpiq AG

Finance Commission

Urs Helfer
Chairman
Axpo Power AG

**Commission for Communication
and Information**

Dr. Philipp Hänggi (until 31.12.2019)
Chairman
BKW Energie AG

Commission for Legal Affairs

Hansueli Sallenbach
Chairman
Axpo Holding AG

Statutory Auditor

PricewaterhouseCoopers AG
Zürich

Management structure

Executive Board of Nagra



Dr. Thomas Ernst
Chief Executive Officer



Dr. Markus Fritschi
Deputy CEO / Division Head Collaboration
Sectoral Plan & Public Outreach



Maurus Alig
Coordinator Major Project Sectoral Plan
Stage 3 / General Licences



Reto Beutler
Division Head Finance, Controlling &
Human Resources



Patrick Senn
Division Head Planning & Construction of
Deep Geological Repositories



Dr. Tim Vietor
Division Head Safety, Geology &
Radioactive Materials

Further members of the Nagra management team



Dr. Irina Gaus
Head of Research & Development



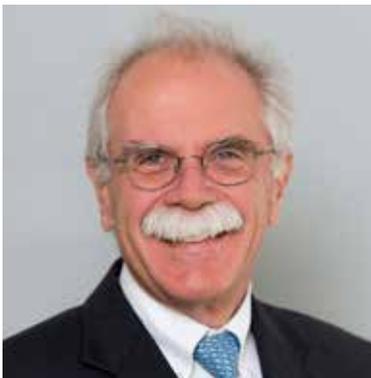
Dr. Harald Maxeiner (until 31.10.2019)
Deputy Division Head Safety, Geology &
Radioactive Materials



Armin Murer
Deputy Division Head Collaboration
Sectoral Plan & Public Outreach

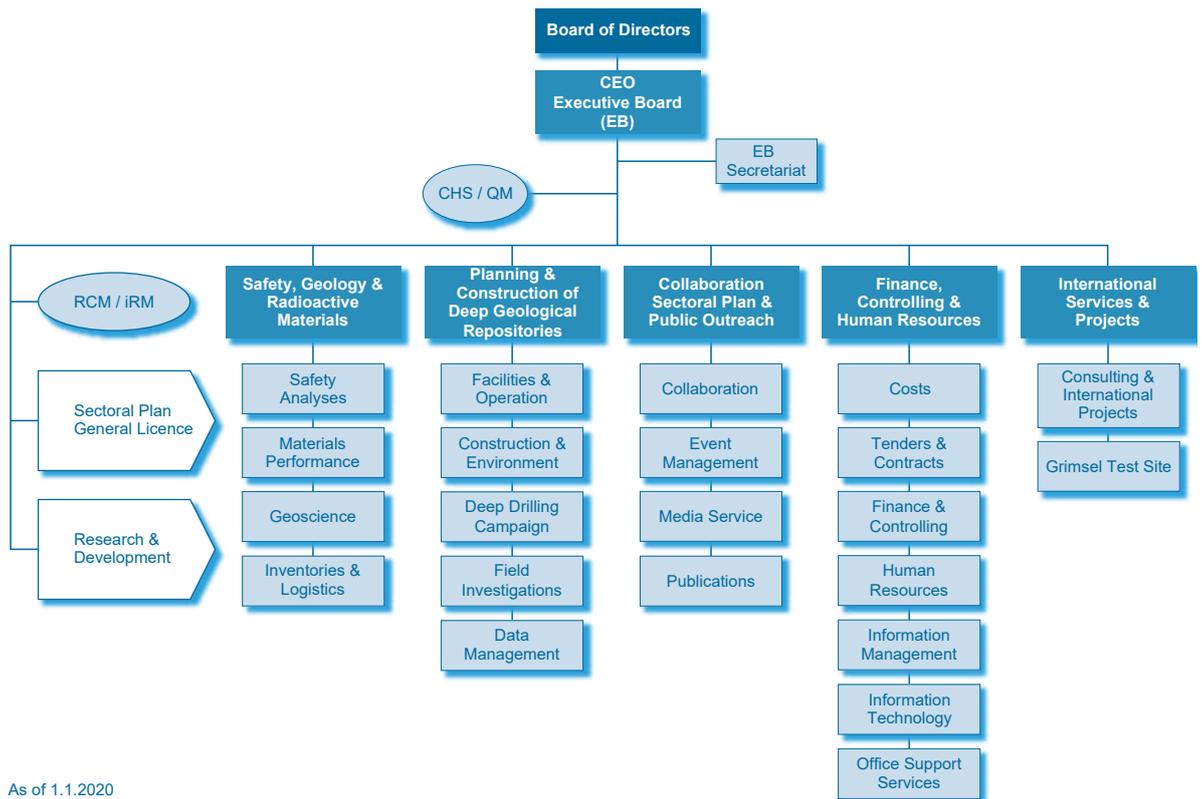


Dr. André M. Scheidegger
Deputy Coordinator Major Project
Sectoral Plan Stage 3



Dr. Stratis Vomvoris
Division Head International Services &
Projects

Organigram of the head office



As of 1.1.2020

RCM: Requirements and Configuration Management
 iRM: integrated Risk Management
 OHS: Occupational Health and Safety
 QM: Quality Management

Head office

At the end of 2019, Nagra had 134 employees excluding apprentices (123 permanent employees and eleven temporary employees). Together, they fill 118.5 full-time positions [apprentices excluded].



DR. HARALD MAXEINER

Dr. Harald Maxeiner, member of the Nagra management team, retired at the end of October 2019. Since 1992, the physicist has contributed hugely to the knowledge related to the inventorying and logistics of radioactive waste. In his more than 27 years with Nagra, he was responsible for radioactive materials as a section and division head. In 2016, he assumed the function of deputy division head for "Safety, Geology & Radioactive Materials". On an international level, he was involved with the NEA in a working group on decommissioning of nuclear power plants. His contact network and his relationships with other waste management organisations were a valuable asset to Nagra. Harald Maxeiner continues to work for Nagra as a consultant.



Annual financial statements 2019

Comments on the annual financial statements 2019

The current financial statements for 2019 were prepared in line with the provisions of the relevant Swiss legislation, in particular the articles on commercial accounting and financial reporting of the Code of Obligations for individual financial statements (Art. 957 to 962).

Total expenditure minus proceeds from sales of goods and services and other income is borne by the members of the Cooperative, which results in a balanced year-end result.

The contributions of members of the Cooperative increased by a total of CHF 30.7 million compared to the previous year, which is mainly due to the first deep boreholes in Bülach and Trüllikon conducted as part of the deep drilling campaign initiated in 2019.

The net proceeds from sales of goods and services decreased slightly (-CHF 0.4 million), and the other operational costs, depreciation and the financial result increased by a total of CHF 0.1 million.

Further information can be found in the notes to the annual financial statements.

Wettingen, 19th March 2020



Dr. Thomas Ernst, Chief Executive Officer

Income statement

Note		1.1.–31.12.2019	1.1.–31.12.2018
		CHF	CHF
C1	Net proceeds from sales of goods and services		
	Net proceeds from services for third parties	2 412 276	2 336 907
	Research contributions from third parties	237 581	562 861
	Net proceeds from services for Cooperative members	365 414	540 520
	Total net proceeds from sales of goods and services	3 015 271	3 440 288
C2	Contributions of members of the Cooperative		
	Contributions to administration costs	700 000	700 000
	Contributions to project expenditure	91 749 748	61 064 102
	Total contributions of members of the Cooperative	92 449 748	61 764 102
	Other operating income	187 674	88 771
	Operating income (total output)	95 652 693	65 293 161
C3	Cost of materials (project expenditure)	72 052 823	37 249 014
C4	Staff costs	20 379 311	19 326 831
C5	Other operational costs	2 874 193	2 783 333
C10	Depreciation and value adjustments on fixed assets	202 455	205 314
	Operating result	143 911	5 728 669
	Financial income	-214 935	-123 414
	Financial costs	229 204	87 977
	Ordinary result	129 642	5 764 106
C4	Extraordinary, non-recurring or prior-period expenditure	-	5 650 393
	Annual profit before taxes	129 642	113 713
	Direct taxes	129 642	113 713
	Annual profit (annual loss)	-	-

Balance sheet

Note	Assets	31.12.2019 CHF	31.12.2018 CHF
	Current assets		
	Cash and cash equivalents	16 530 924	18 028 645
C6	Trade receivables	894 803	446 932
	Due from third parties	698 278	446 932
	Due from members of the Cooperative	196 525	–
C7	Other current receivables	1 227 873	172 340
	Towards third parties	1 227 873	172 340
C8	Non-invoiced services	2 285 870	2 004 605
C9	Accrued income and prepaid expenses	942 763	379 957
	Total current assets	21 882 233	21 032 478
	Capital assets		
C10	Tangible fixed assets	1 566 408	1 530 341
	Total capital assets	1 566 408	1 530 341
	Total assets	23 448 641	22 562 819
	Equity and liabilities		
	Current borrowed capital		
C11	Trade payables	6 719 568	6 927 677
	Due to third parties	6 394 386	6 921 285
	Due to members of the Cooperative	325 182	6 392
	Other current liabilities	735 725	1 770 044
	Due to third parties	735 725	1 765 704
	Due to members of the Cooperative	–	4 340
C12	Advance payments received	3 504 946	1 766 458
C13	Deferred income and accrued expenses	12 348 402	11 958 640
	Total current borrowed capital	23 308 641	22 422 819
	Total liabilities	23 308 641	22 422 819
C14	Equity		
	Cooperative capital	140 000	140 000
	Annual profit (annual loss)	–	–
	Total equity	140 000	140 000
	Total equity and liabilities	23 448 641	22 562 819

Notes to the annual financial statements

A) General information

Accounting legislation

The current financial statements were prepared in line with the provisions of Swiss law, in particular the articles on commercial accounting and financial reporting of the Code of Obligations for individual financial statements (Art. 957 to 962).

Company, name, legal form and registered office

Nagra, National Cooperative for the Disposal of Radioactive Waste,
Hardstrasse 73, Postfach 280, 5430 Wettingen

Type of audit

According to legal requirements (Art. 727 par. 2 of the Code of Obligations), the annual financial statements of Nagra are subject to an ordinary audit.

Currency used for the accounting

The accounting is in the national currency (Swiss Francs; CHF).

Cash flow statement

The cash and cash equivalents form the basis for the presentation of the cash flow statement. Cash flow from operating activities is calculated using the indirect method.

Approval of the annual financial statements

The Board of Directors approved the annual financial statements on 19th March 2020 on behalf of the annual general meeting.

B) Information on the principles applied in the annual financial statements

The main positions in the annual financial statements are assessed as follows:

Cash and cash equivalents

Cash and cash equivalents comprise petty cash and credit balances on bank accounts. They are carried at nominal value. Foreign currency positions are carried at the exchange rate on the reporting date.

Trade receivables

Trade receivables are reported at the invoiced amount minus the allowances made for the bad debts provision. The allowance is formed based on the maturity structure and recognisable credit risks.

Receivables and payables towards involved parties

These positions are exclusively receivables and payables towards involved parties (i.e. the members of the Cooperative).

Non-invoiced services

The capitalised work in progress and the received advance payments result exclusively from contracts for third parties. For the ongoing projects, all expenditure is capitalised in work in progress, and all advance payments received are booked as a liability.

Fixed assets

Fixed assets are reported at acquisition cost minus the accumulated depreciation over the estimated useful lifetime of each asset category. Investments in hardware below CHFk 20 (one-off) and software below CHFk 100 (one-off) are debited directly to the income statement.

The lifetimes for depreciation fall within the following bandwidths for the individual categories that are relevant for Nagra:

Land	Depreciation only in the case of value impairment
Buildings	20 to 50 years
Operating and business equipment	5 to 10 years
IT hard- and software	2 to 3 years

Tenant fixtures are written off over the duration of the tenancy or, if shorter, over the useful lifetime of the asset, or are debited directly to the income statement.

Expenditure on repairs and maintenance that does not add value is debited directly to the income statement. Renewals that change the useful lifetime of assets are capitalised.

Assets removed from operation or sold are written off on the assets account at their acquisition values and the accumulated depreciation. The resulting profits or losses are entered in the income statement.

Payables

All payables are carried at nominal value. Services received and incurred liabilities are deferred according to the period.

Provisions

Provisions are formed when, based on events that have occurred in the past, the company has a legal or factual obligation, the extent and due date of which are unknown but can be estimated.

C) Information, breakdowns and notes to the annual financial statements**C1) Net proceeds from sales of goods and services**

The slight increase in incoming orders from third parties resulted in a small increase in the proceeds from third parties. As no larger research project was settled in 2019, research contributions showed a slight decrease.

C2) Contributions of the members of the Cooperative

The contributions of the members of the Cooperative are invoiced on a quarterly basis according to the budget approved by the Board of Directors. A deviation from the budget leads to an additional charge or a credit that is booked in the year of accounting as prepaid expenses or deferred income. This results in an annual profit of CHF 0.

According to the decision of the ordinary general meeting held on 26th June 2018, the implementation of the special agreement on Nagra's financing resulted in assets and liabilities between the NPP operators of CHF 1.3 million due to future compensation payments. The balance for Nagra is zero, which is why the individual positions are not included in the financial statement for 2019.

C3) Cost of materials (project expenditure)

The project expenditure is made up as follows:

Project-related external services for:	2019	2018
	CHFk	CHFk
Projects: – deep borehole campaign	39 596	6 494
– others	20 614	19 189
Communication	1 716	1 904
Fees (ENSI, SFOE)	9 325	9 097
Travel expenses	802	565
Total	72 053	37 249

C4) Staff costs

Staff costs, including social contributions, increased by 5.4% to CHFk 20 379 compared to the previous year. The higher expenditure is due mainly to an increase in the staffing level. The average staffing level in 2019 was 107.8 full-time positions, 7.8 temporary positions and 1.6 internships (2018: 100.6 full-time positions, 5.2 temporary positions and 1.4 internships). In 2018, extraordinary expenditure included a buy-in to the higher coverage rate of the defined contributions scheme in the amount of CHF 5.65 million.

C5) Other operational costs

Other operational costs include rents and expenditure on property of CHFk 1 121, expenditure on informatics of CHFk 676 and further operational costs of CHFk 1 077.

C6) Trade receivables

The increase compared to the previous year (CHFk 448) is due mainly to new international projects.

C7) Other current receivables

Other current receivables mainly include cash contributions for securing the centralised billing procedure of the Swiss Federal Customs Administration (CHFk 800) and for domestic and foreign VAT credit balances (EURk 354).

C8) Non-invoiced services

Non-invoiced services consist of accrued internal services and third-party services for various projects. As a result of an increased order backlog, the amount is higher than in 2018.

C9) Accrued income and prepaid expenses

Accrued income and prepaid expenses comprise the balance of the year-end result (CHFk 559), the pre-payments for Suva 2020 (CHFk 151) and different other positions (CHFk 233).

C10) Tangible fixed assets

	Land and buildings	Office and workshop	Vehicles	Total
	CHFk	CHFk	CHFk	CHFk
Acquisition value per 01.01.2018	1 825	955	692	3 472
Additions		6		6
Disposals				
Reclassifications ⁽¹⁾			-23	-23
Acquisition value per 31.12.2018	1 825	961	669	3 455
Additions		118	121	239
Disposals			-31	-31
Reclassifications				
Acquisition value per 31.12.2019	1 825	1 079	759	3 663
Accumulated depreciations per 01.01.2018	465	777	500	1 742
Additions	30	111	65	206
Disposals				
Reclassifications ⁽¹⁾			-23	-23
Accumulated depreciations per 31.12.2018	495	888	542	1 925
Additions	30	101	72	203
Disposals			-31	-31
Reclassifications				
Accumulated depreciations per 31.12.2019	525	989	583	2 097
Carrying value per 01.01.2018	1 360	178	192	1 730
Carrying value per 31.12.2018	1 330	73	127	1 530
Carrying value per 31.12.2019	1 300	90	176	1 566

(1) Correction for 2015

C11) Trade payables

Compared to the previous year, trade payables decreased slightly by CHFk 209 to CHFk 6 720. The agreed trade discount was applied more frequently.

C12) Advance payments received

Advance payments received are for accrued internal services and third-party services for various projects. Due to the higher volume of third-party contracts, the advance payments received as per 31.12.2019 (CHFk 3 505) are higher than in the previous year (CHFk 1 766).

C13) Deferred income and accrued expenses

Deferred income consists mainly of outstanding amounts for services in the amount of CHFk 8 490 for services rendered in connection with the deep borehole campaign. Additional deferrals include fees of the SFOE for the 4th quarter of 2019 in the amount of CHFk 1 126 and expenditure of the head office in the amount of CHFk 916. The deferral for outstanding vacation time and overtime amounts to CHFk 1 816.

C14) Equity

The Cooperative capital is unchanged with CHFk 140 and is divided into 140 share certificates of CHF 1000 each, with 7 certificates of 20 shares each being distributed.

D) Further information

Liabilities towards pension schemes

As of 31.12., there were the following liabilities towards pension schemes:	31.12.2019	31.12.2018
	CHF	CHF
Contribution statement December	242 573	226 494
Final account from buy-in to the contributions scheme	-	391 946

Contingent liabilities

Nagra is not involved in any legal actions, legal disputes, regulatory or tax investigations, inquiries or other legal procedures that could have financial consequences for the annual financial statements for 2019.

As of 31st December 2019, there were no guarantee obligations.

Risk report 2019

On 25th June 2019, the Board of Directors approved Nagra's risk report for 2019.

Remuneration disclosure of the Statutory Auditor

(in accordance with Art. 961a of the Code of Obligations)

The Statutory Auditor claimed the following remuneration:

	2019	2018
	CHF	CHF
Ordinary audit of the annual financial statements	24 000	24 000
Additional audits	18 000	9 700
Total	42 000	33 700

[excluding expenses and VAT]

Accumulated accounts including adjustments

Note	Total income	31.12.2018			31.12.2019		
		Increase 2018 CHF	Excluding interest: adjustment payments 2018 CHF	Status 31.12.2018 CHF	Increase 2019 CHF	Excluding interest: adjustment payments 2019 CHF	Status 31.12.2019 CHF
	Swiss Confederation	1 763 714	-	42 298 265	2 650 008	-	44 948 273
	Axpo Power AG	13 775 318	-310 626	316 374 434	20 660 514	-	337 034 948
	BKW Energie AG	7 282 544	-595 641	149 752 484	10 550 175	-	160 302 658
	Kernkraftwerk Gösgen-Däniken AG	16 318 503	1 252 198	409 952 323	25 048 901	-	435 001 224
	Kernkraftwerk Leibstadt AG	21 924 023	-345 931	486 668 089	32 840 150	-	519 508 240
	Contributions to project expenditure	61 064 102	-	1 405 045 595	91 749 748	-	1 496 795 343
	Contributions to administration costs	700 000	-	90 970 000	700 000	-	91 670 000
	Contributions of Cooperative members to Nagra	61 764 102	-	1 496 015 595	92 449 748	-	1 588 465 343
	Contributions GNW	-	-	65 265 331	-	-	65 265 331
E1	Total contributions	61 764 102	-	1 561 280 926	92 449 748	-	1 653 730 674

	Increase 2018 CHF	Status 31.12.2018 CHF	Increase 2019 CHF	Status 31.12.2019 CHF
Appendix Total expenditure				
Geoscientific studies	6 679 268	217 376 704	15 181 643	232 558 347
Nuclear technology and safety	1 587 273	54 423 010	2 129 156	56 552 166
Radioactive materials	1 565 677	48 631 361	1 337 811	49 969 172
Facility planning	1 687 138	34 635 875	1 596 972	36 232 847
Generic (non-site-specific) work	3 865 065	116 371 536	3 452 948	119 824 484
General programme costs	6 675 835	105 009 354	4 721 386	109 730 740
Fees and compensation	4 548 514	74 559 716	4 662 594	79 222 310
L/ILW programme	26 608 770	651 007 556	33 082 510	684 090 066
Geoscientific studies	13 065 527	379 085 007	38 897 370	417 982 377
Nuclear technology and safety	2 354 940	79 101 224	3 278 818	82 380 042
Radioactive materials	939 449	29 039 452	1 341 149	30 380 601
Facility planning	1 840 428	29 610 199	2 200 785	31 810 984
Generic (non-site-specific) work	4 530 974	135 924 864	3 909 419	139 834 283
General programme costs	7 175 519	90 262 104	4 377 106	94 639 210
Fees and compensation	4 548 495	76 280 520	4 662 591	80 943 111
HLW programme	34 455 332	819 303 370	58 667 238	877 970 608
E2 Project expenditure for repository programmes	61 064 102	1 470 310 926	91 749 748	1 562 060 674
Administration and general project expenditure	700 000	90 970 000	700 000	91 670 000
Total expenditure for L/ILW and HLW programmes, administration and general project expenditure	61 764 102	1 561 280 926	92 449 748	1 653 730 674

Notes to the accumulated accounts

The accumulated treatment of the contributions of the members of the Cooperative and the application of these contributions forms the basis, at the time of waste disposal, for any adjustments of payments among the members. It also indicates which work has resulted in project-related expenditure.

The structure of the total income is oriented primarily to the operating accounts.

E1) Contributions of the members of the Cooperative

The contributions of the members of the Cooperative towards covering project costs are calculated based on the thermal output, the service lifetime-weighted output and the expected waste volumes of the individual nuclear power plants of the members.

The contributions of the members in the total amount of CHF 92.4 million (CHF 61.8 million in the previous year) correspond to those in the income statement. A contribution of CHF 0.7 million to administration costs is included.

The implementation of the special agreement on the financing of Nagra in accordance with the decision of the extraordinary general meeting held on 18th September 2017 and the ordinary general meeting held on 26th June 2018 results in compensation payments among the involved parties of CHF 1.3 million in 2019. The members of the Cooperative have agreed to disclose the compensation payments nominally (i.e. without corresponding interest).

The GNW contributions include payments by GNW for contract work on the Wellenberg project. This project is terminated.

As a result of the decision of the Federal Council on 27th September 2019, a comprehensive compensation payment will be initiated in 2020. In total, the Federal Government will compensate the insufficient contributions made in the past by paying CHF 137.2 million (plus VAT) that will be divided among the NPP operators. The corresponding invoice and forwarding of the repayment by the Federal Government to the NPP operators will be managed by Nagra. This transaction will not appear in either the financial statement for 2020 or in the accumulated accounts for 2020.

E2) Project-specific expenditure for the repository programmes

The two repository programmes (L/ILW and HLW) basically have the same structure in the presentation of the accumulated accounts and are oriented towards the most important technical tasks to be performed up to the completion of waste disposal activities. If there is no explicit reference to a specific programme, the following explanations of the individual positions apply to both projects.

a) Geoscientific investigations

Geological investigations for identifying potential siting regions comprise geological studies in the investigation area of Northern Switzerland for the deep geological disposal of high-level waste, as well as the processing of geological information for the low- and intermediate-level waste repository.

b) Nuclear technology and safety

The work comprises the safety-based evaluation of potential siting regions as well as laboratory studies on the near-field and on the different backfill materials.

c) Radioactive materials

This includes expenditure on assessing the disposability of waste packages and on ongoing documentation and inventorying of radioactive waste.

d) Facility planning

This position includes expenditure on developing the concepts for the surface and underground facilities for the repositories for HLW and L/ILW.

e) Generic (site-independent) investigations

This includes work on developing methodologies, modelling and validation of the models used in safety analyses, laboratory studies, participation in the work in the rock laboratories (Grimsel and Mont Terri) and the research programmes of the EU.

f) General programme costs

This expenditure results from programme management, expenditure on cost studies and public relations activities.

g) Fees and compensation

This includes the fees passed on to Nagra from the regulatory and safety authorities.

Report of the statutory auditor to the General Meeting of Nagra, National Cooperative for the Disposal of Radioactive Waste

Report of the statutory auditor on the financial statements

As statutory auditor, we have audited the accompanying financial statements of Nagra, National Cooperative for the Disposal of Radioactive Waste, which comprise the income statement, balance sheet, cash flow statement and notes, for the year ended 31st December 2019.

Management's responsibility

Management is responsible for the preparation of the financial statements in accordance with the requirements of Swiss law and the Cooperative's articles of incorporation. This responsibility includes designing, implementing and maintaining an internal control system relevant to the preparation of financial statements that are free from material misstatement, whether due to fraud or to error. Management is further responsible for selecting and applying appropriate accounting policies and making accounting estimates that are reasonable in the circumstances.

Auditor's responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with Swiss law and Swiss Auditing Standards. Those standards require that we plan and perform the audit to obtain reasonable assurance whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or to error. In making those risk assessments, the auditor considers the internal control system relevant to the entity's preparation of the financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the entity's internal control system. An audit also includes evaluating the appropriateness of the accounting policies used and the reasonableness of accounting estimates made, as well as evaluating the overall presentation of the financial statements. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Opinion

In our opinion, the financial statements for the year ended 31st December 2019 comply with Swiss law and the Cooperative's articles of incorporation.

Report on other legal requirements

We confirm that we meet the legal requirements on licensing according to the Auditor Oversight Act (AOA) and independence (article 906 CO in connection with article 728 CO) and that there are no circumstances incompatible with our independence.

In accordance with article 906 CO in connection with article 728a paragraph 1 item 3 CO and Swiss Auditing Standard 890, we confirm that an internal control system exists which has been designed for the preparation of financial statements according to the instructions of Management.

We recommend that the financial statements submitted to you be approved.

PricewaterhouseCoopers AG



Thomas Wallmer
Audit expert
Auditor in charge



Jonas Schwegler
Audit expert

Zürich, 19th March 2020

Appendices

Waste inventories and volumes

Radioactive waste arises mainly from electricity production in the five Swiss nuclear power plants. It is also produced from the use of radioactive materials in the areas of medicine, industry and research (MIR waste).

Waste volumes at the end of 2019

Nagra maintains a centralised database of all waste packages as a service to the waste producers. The following table shows the volumes and activities of waste prepared for geological disposal as of the end of 2019. The table does not contain pre-conditioned raw wastes and waste packages prepared for processing in the Zwilag plasma furnace, for example.

Conditioned waste (31st December 2019, figures rounded)	Volume (m³)	Activity (Bq)
Nuclear power plants	3 506	$2.6 \cdot 10^{15}$
Zwilag	2 466	$7.4 \cdot 10^{18}$
Federal Government's interim storage facility (MIR) (waste from medicine, industry and research)	1 592	$1.2 \cdot 10^{16}$

The Zwilag waste consists of waste packages delivered to the interim storage facility from the power plants, waste packages from the plasma furnace and steel flasks with vitrified high-level waste from reprocessing.

Predicted waste volumes and inventories for deep geological disposal

Planning the geological repositories requires input in the form of information on expected waste volumes. The total volume of waste for disposal will be around 92 000 cubic metres packaged in disposal containers (see table for details). The volume of waste from the NPPs and Zwiilag results from the given operating lifetimes; the volume of waste from medicine, industry and research is based on the end of operation of the L/ILW repository.

Predicted waste volumes (47-/60-year NPP operation) ¹	L/ILW (m ³)		ATW (m ³) ²		HLW/SF (m ³)	
	conditioned	packaged	conditioned	packaged	conditioned	packaged
BA-KKW Operational waste from the NPPs (from cleaning systems and mixed waste), incl. post-operational phase	8 320	31 249				
RA-KKW NPP reactor waste (activated components)	478	1 811				
SA-KKW NPP decommissioning waste	18 378	26 803				
WA-KKW NPP reprocessing waste			99	414	114	398
BA-ZWI Zwiilag operational waste	6	22				
SA-ZWI Zwiilag decommissioning waste	461	563	24	24		
BA-MIF MIR waste collected from the FOPH and operational waste from PSI	3 645	8 432	168	634		
SA-MIF Decommissioning waste from PSI and CERN	10 578	10 578				
BEVA/OFA Waste from the future encapsulation/surface facilities for the L/ILW & HLW repositories	651	2 302				
SF Spent fuel assemblies					1 365	9 004
Total volumes	42 517	81 760	291	1 072	1 479	9 402
Percentage (rounded)	96.0%	88.6%	0.7%	1.2%	3.3%	10.2%
Activity [Bq]³	7.9 · 10 ¹⁶ Bq		2.2 · 10 ¹⁶ Bq		1.9 · 10 ¹⁹ Bq	
Percentage	0.4%		0.1%		99.5%	

¹ Basis: Waste Management Programme and Cost Study 2016
Operating lifetime: NPP Mühleberg 47 years (till 2019), other NPPs 60 years
Takes into account the planned revision of the Radiological Protection Ordinance and decay storage of radioactive materials for a maximum of 30 years with subsequent conventional disposal
For explanations on the current waste volumes compared to previous modelling assumptions (MIRAM), see Nagra NTB 16-01

² Alpha-toxic waste

³ Activity inventory for reference year 2075

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