nagra. we care

annual report 2020

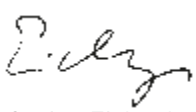
Corina Eichenberger,
President of the Board of Directors

Nagra has been drilling deep boreholes in the three siting regions Jura Ost, Nördlich Lägern and Zürich Nordost since 2019. In 2020, drilling was conducted in Trüllikon and Marthalen in Zürich Nordost and in Bözberg in Jura Ost. The second borehole in the Nördlich Lägern siting region, Stadel-3, started at the end of 2020, and the third, Stadel-2, started at the beginning of 2021. These boreholes allow Nagra to complete the picture of the underground in each region. A visit to a drill site gave me the opportunity to experience first-hand how demanding and challenging the work is and how the initial results are evaluated immediately on site. I found the tour very impressive!

The deep borehole campaign has not yet been completed, but I am convinced that, at the end, Nagra will have a solid data basis for comparing the siting regions. This safety-based and transparent approach is the only way to identify the most suitable site for a deep geological repository. I am optimistic that we will continue to make good progress in the final stage of the Sectoral Plan process and master the remaining challenges together.

We will remember 2020 for many years to come. It was a very unusual year that shook up our everyday lives. I was very pleased that Nagra continued to make great strides with its work despite the coronavirus. Nagra employees worked remotely whenever necessary and possible, and most projects were carried out as planned. This is not something I take for granted. Even though complying with all the necessary protective measures required additional effort, drilling continued at full capacity throughout the entire year. Nagra's achievements were only possible as a result of the great commitment, persistence and flexibility of its employees.

I am well aware of the difficult and challenging situation. All the more reason, also on behalf of my colleagues from the Board of Directors, for me to express my sincere gratitude to all Nagra employees and the Executive Board for their great dedication.



Corina Eichenberger

Thomas Ernst,
Chief Executive Officer

2020 taught us to accept the inevitable and do our best to achieve our goals despite the Covid-19 pandemic. Nagra was largely successful in this endeavour.

After years of discussions with the affected Cantons, the Federal Government's replies to central questions regarding groundwater protection in the vicinity of surface facilities provided the necessary clarity. We now have a solid basis for the upcoming procedural steps, and it is now possible to optimise the placement and layout of the surface facilities. Following an analysis of the situation, the future site for the spent fuel encapsulation plant will either be at a repository site or the interim storage facility (Zwilag) area.

Within the framework of the deep borehole campaign, our international drilling teams successfully conducted four boreholes according to schedule and carried out the corresponding investigations. This required great commitment and solution-oriented collaboration with the authorities. The deep borehole campaign has not been hampered by legal constraints and all legally required permits have been obtained. I sincerely congratulate everyone who contributed to this great achievement!

So far, our findings are promising: it is possible to construct a safe deep geological repository in all three siting regions and spatial conditions would allow the construction of a combined repository in all three cases. This is encouraging because a combined repository has significant advantages over two individual repositories in both ecological and economic terms.

Due to the consolidating data basis, selecting the site for the general licence application will hopefully proceed as planned for 2022. ENSI's revised Guideline G03 for deep geological repositories also provides additional guidance for preparing the application. The progress made in the site selection process in 2020 is very gratifying. Unfortunately, personal dialogue often had to remain limited. For this reason, it is important to me to express my sincere gratitude to everyone who has contributed to this success.

Thomas Ernst

"I often have to be present at the drill site. Due to Covid-19, we introduced stricter safety measures early on and limited personnel to a minimum. Coordinating the work has become much more challenging."

Matthias Ammen
Senior Project Manager Drilling Technology & Head of Safety

"I calculate the weight and volume of Switzerland's radioactive waste. Working from home let me organise my working hours more flexibly, which made it easier to balance my job and look after my four-year-old daughter."

Carolin Fichtner, Project Manager in the Inventory & Logistics Section

"I research processes such as erosion and climate evolution. The mix of working from home and going to the office gave me a degree of flexibility that was particularly useful in phases requiring high concentration. Thanks to the excellent IT infrastructure, online technical exchanges worked just as well from home. On a personal note, the border closure in the spring was very difficult for me as my grown-up daughter was unable to visit me for months."

Angela Landgraf
Section Head Long-term Geological Evolution

"My work routine changed entirely in 2020. Many guided tours of the underground rock laboratories or drill sites had to be cancelled and trade fairs and local events couldn't take place. When we were allowed to arrange an event, we had to comply with very strict safety concepts. I really hope that we will soon be able to communicate in person again."

Heinz Sager, Section Head Event Management

"Unfortunately, we couldn't hold any company events. We were unable to organise a suitable send-off for our retiring colleagues and could not welcome new colleagues in person. Implementing the protective measures involved a lot of work for the Office Support Services. We provided hygiene products and made sure that the offices were disinfected thoroughly every day. We also purchased and maintained air purification systems and CO_2 measurement devices for larger offices."

Christine Esslinger
Office Support Services

Guiding principles of waste management

How are waste management and financing regulated? What is the time schedule? 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 set out 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 waste disposal.

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.

In accordance with the revised Nuclear Energy Act, 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 2020, the Swiss Federal Nuclear Safety Inspectorate (ENSI) published the revised ENSI G03 Guideline on Deep Geological Repositories. It reflects the latest international recommendations.

Approach to waste management

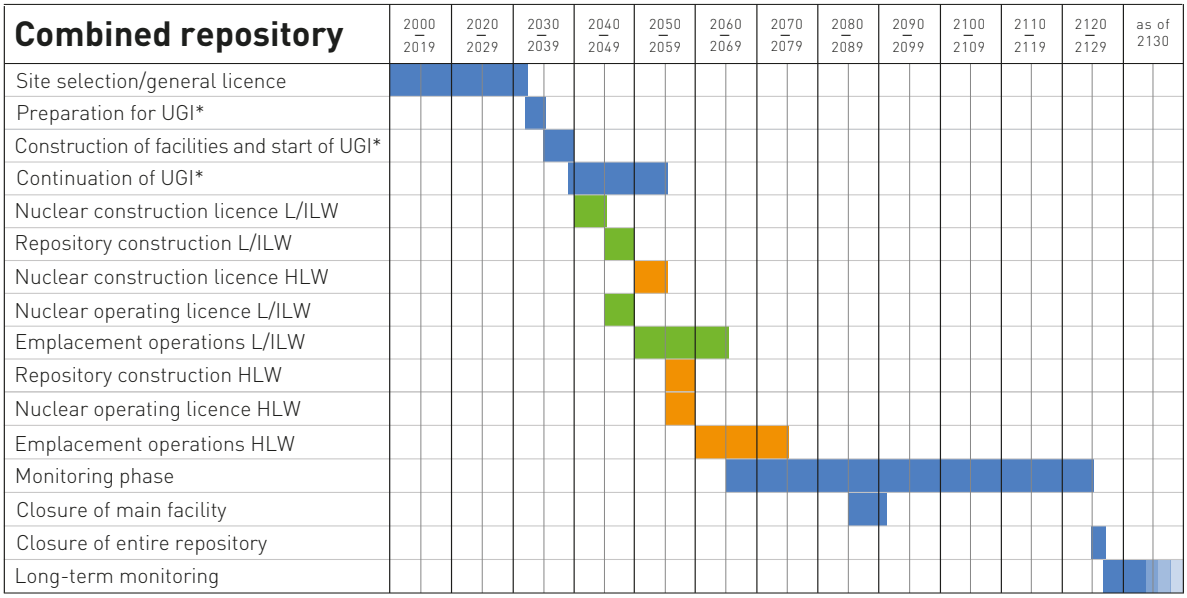
Nagra's two feasibility demonstrations for low- and intermediate-level waste (L/ILW) and high-level waste (HLW) were approved by the Federal Council and show that safe deep geological repositories can be constructed in Switzerland. The Waste Management Programme describes the procedures for the planning, construction, operation and closure of deep geological repositories. It also includes a realisation plan as well as information on the allocation of radioactive waste to the repositories and on the repository conceptual design.

Nagra has to update its Waste Management Programme every five years and submit it to the federal authorities. In 2021, Nagra will submit both the next Programme and the updated Research, Development and Demonstration Plan. The Cost Study will be updated and submitted at the same time.

In Switzerland, radioactive waste and materials arise from the generation of nuclear energy in 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 an implementation plan for a combined repository (see illustration). This describes the basic sequence of activities and outlines the work that has to be done up to the closure of the repositories.

Securing the funding

The Waste Disposal Fund secures the costs of disposing of the radioactive waste that arises after the final decommissioning of a nuclear power plant. 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



Realisation timetable for the combined repository based on current planning

* UGI = underground geological investigations

electricity generated with nuclear power, the consumer pays around one Rappen (= cent) per kilowatt hour to finance decommissioning and waste disposal. At the end of 2020, the accumulated capital in the Waste Disposal Fund amounted to around CHF 6.0 billion and in the Decommissioning Fund to around CHF 2.8 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 current Cost Study 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 nuclear facilities into the Decommissioning and Waste Disposal Funds.

In November 2019, the Federal Council decided on a revision of the Decommissioning and Waste Disposal Funds Ordinance (SEFV), which entered into effect on 1st January 2020. The Federal Government is also a member of the Nagra Cooperative and makes annual contributions to costs for disposal of waste arising from applications in medicine, industry and research. Calculations showed that these contributions had been too low for years. The Federal Government therefore settled its accumulated federal debt with a one-off payment in 2020 and adjusted its annual contributions for the disposal of waste from medicine, industry and research. The revision of the Ordinance on Radiation Protection Fees entered into effect on 1st February 2021.

On track despite the coronavirus

The pandemic and its consequences have also impacted Nagra. Thomas Ernst talks about the deep borehole campaign and key results, and explains how the discussions surrounding the surface infrastructure of a deep geological repository are proceeding. He also presents an outlook for the upcoming years.

Thomas Ernst, was 2020 a bad year because of the coronavirus – or a good year despite it?
I would like to differentiate here: for our country, indeed for all of humanity, 2020 was certainly a bad year because of the coronavirus. In Switzerland alone, over 7500 more deaths were recorded than usual. Many people were, or still are, ill and many are struggling with long-term effects. The economic consequences are also difficult to predict. For Nagra, 2020 was a good year overall. The virus affected our work only partially, and thankfully we were well prepared. At the end of 2019, we had introduced new tools for online collaboration, meaning that from the beginning of 2020 we had the technical resources to work from home. This was a stroke of luck. However, personal interaction and informal exchanges, which are also important, have clearly suffered.

> "We managed to continue our deep borehole campaign without restrictions and delays."

But boreholes can't be drilled from home.
No, of course not. We managed to continue our deep borehole campaign without undue restrictions and delays, and I'm very pleased about that. In the spring, having to interrupt the drilling was a realistic scenario, but we were able to avert this. One of the biggest challenges was how to allow international drilling teams with specialists from all over the world to enter and leave Switzerland? Finding a solution to this required a considerable additional effort. Fortunately, collaboration with the authorities went very well.

How was that possible? Were the borders not closed?
We needed exemption permits. The borders were primarily closed to tourists, but it was possible to enter and leave for work reasons. However, the drilling teams had to commit themselves to restricting their movements to their accommodations and the drill sites. They were not allowed, for example, to visit a restaurant.

What would have been the consequences of interrupting the boreholes?
An interruption could have resulted in the borehole becoming unstable. We would have had to begin drilling anew, which would have led to long delays and additional costs amounting to millions.

So, the boreholes are on track. What key insights were gained in 2020?
Our overall geological understanding has been confirmed. We now know that all three regions Jura Ost, Nördlich Lägern and Zürich Nordost are suitable for the construction of a deep geological repository.

Wasn't it already known that these three regions are suitable?
Yes, but we were able to solidly confirm this assessment. We also saw that there are differences between the regions after all.

What kind of differences?
We can see that the Opalinus Clay, the rock that will eventually host the repository, is between 105 and 120 metres thick in all three regions. It also has the properties we need, being consistently tight and homogeneous. The Opalinus Clay should therefore provide no significant reason to distinguish between the siting regions. This is an important insight from the year 2020. The most important differences are in the rock formations above and below the Opalinus Clay, the so-called confining geological units. These

differences could be decisive and must now be analysed in depth. We will develop a safety-based comparison based on all findings and finally propose where to construct the deep geological repository.

What is still needed for Nagra's siting proposal?
In addition to existing information for the Jura Ost and Zürich Nordost regions, we had results from two new boreholes in each of these siting regions by the end of 2020. This provides us with a solid data basis. For Nördlich Lägern, we have initial information from a new borehole in Bülach. The two Stadel boreholes in this region are therefore of great importance, and only when these have been completed can we compare the three regions.

In summary then, it is possible to say that the boreholes are proceeding as planned.
Yes, absolutely. During the campaign, we have gained a lot of experience and are now able to drill a high-quality borehole and conduct all tests within six months.

Another important topic in 2020 was the surface infrastructure, in particular the site for the encapsulation plant. Where are we on this issue?
Nagra demonstrated in a report that it makes sense to construct an encapsulation plant either at the repository site or at the interim storage facility. Locating it at a "greenfield site" or a nuclear power plant has ecological and operational disadvantages. The opinion that an encapsulation plant should either be constructed at the "sender" location, namely the Zwilag interim storage facility, or at the "recipient" location, the deep geological repository, is widely shared.

Which option does Nagra prefer?
We presented both options for discussion on equivalent terms. The transregional collaboration with the regions and Cantons has not yet led to a consensus. It is now our task to select a site taking the differing position statements into consideration. A decision is expected for 2022.

The surface infrastructure gave rise to a controversial debate on the subject of groundwater. For years, the discussion has focused on whether a surface facility should, or can, be constructed above groundwater. Has there been any progress on this question in 2020?
Today, the Federal Government, Nagra and, more recently, the Cantons agree that it is possible to construct a surface facility in water protection areas

"We now know that all three regions Jura Ost, Nördlich Lägern and Zürich Nordost are suitable for the construction of a deep geological repository."

set aside for groundwater usage and that it can therefore be permitted. At the moment, our focus is on optimising details regarding the individual sites. We are optimistic that we will be able to clarify this issue during 2021.

Why not simply avoid the groundwater if this topic is so controversial?
Of course, we would prefer to be able to avoid all spatial planning conflicts, but groundwater is only one aspect among many. In our densely populated country, it is not possible to find a solution that does not conflict with spatial planning aspects. Our various protected resources have to be given equal weight, which is why we need balanced and safe solutions that satisfy all actors.

In 2020, Nagra not only drilled and talked about encapsulation plants and groundwater but also conducted research in underground rock laboratories. Could you name a flagship experiment of special importance?
The "HotBENT" experiment would fall into this category. It was started at the Grimsel Test Site in 2020 to investigate the thermal loading of the bentonite material that will be used to backfill the repository tunnels. Waste management organisations from nine countries are involved in this experiment, demonstrating that HotBENT research is highly relevant. With this project, we want to determine how hot bentonite can safely become without compromising its barrier performance. The resulting knowledge will impact the repository geometry and the underground space requirements of the deep geological repositories. Should it emerge that the tunnels can be constructed closer together than originally expected, this would mean that the space requirements for the repository could be reduced.

Let's venture an outlook: In autumn 2021, you will retire after serving Nagra as CEO for 14 years. Your successor, Matthias Braun, assumed respon-

“I believe that the most challenging task is to develop a transparent and comprehensible line of argument for why we have decided on one particular region as opposed to another.”

sibility on 1st May 2021. What is most important to you in this “final phase”?
Professionally managing the handover of tasks and know-how is important to me. This will ensure that, under the new leadership, Nagra will be optimally positioned for the siting proposal that we hope to announce in 2022.

After 14 years, what are the most important insights you will pass on to your successor?
Safety has top priority, and that must remain so. To be able to construct a safe repository, we need interdisciplinary expertise and the careful weighing of various opinions. Safety is the common denominator for all actors involved in the procedure. Questions relating to public acceptance or economic efficiency are secondary.

But without acceptance there will be no repository – not even if it can provide maximum safety.
True. This is why the participation procedure and dialogue with the regions are so important – particularly in the region that will eventually be selected for the construction of the repository. Dialogue will be further expanded there.

The choice is now down to three regions. Will the decision be a close one or do you expect a clear result?
I expect a well-justified decision but it is still too early to make predictions. We won’t have borehole results for Nördlich Lägern until early 2021. Only when we have completed all the boreholes and the key results are available will we be able to compare the three siting regions with one another.

What is the biggest hurdle that Nagra still has to overcome before it can make a siting proposal?
I believe that the most challenging task is to develop a transparent and comprehensible line of argument for why we have decided on one particular region as opposed to another. To make this science-based decision transparent and comprehensible to the public at large will be very challenging.

Current status of the deep borehole campaign

The information gained from the deep boreholes in 2020 meets expectations. It confirms that all three siting regions are suitable for the construction of a deep geological repository. However, there are differences between the regions and, at present, it is too early for any statements on site selection.

Nagra has been drilling deep boreholes since 2019 to determine the most suitable site for a deep geological repository. The purpose of the boreholes is to investigate the underground in the Nördlich Lägern, Zürich Nordost and Jura Ost siting regions. Rock samples and measurements in the borehole provide information on the Opalinus Clay and the rock formations lying above and below it. The repository will eventually be constructed in the Opalinus Clay.

Deep boreholes in Nördlich Lägern

The Bülach borehole was completed in 2019 and the drill site has been dismantled. Rock samples and measured data were analysed and Nagra is pleased with the results: the Opalinus Clay is very tight. It is located at a depth of 900 metres and thus deeper than in other regions. The ancient, fossilised coral reef that was encountered above the Opalinus Clay in the Bülach borehole proved to be tight. Nagra originally assumed that constructing a repository with its many tunnels would be more difficult at this depth, but investigations have shown that this siting region is better suited from an engineering point of view than expected. A repository can be constructed at this depth and therefore also in this region. As the underground picture is not yet complete in this siting region, Nagra is drilling two more deep boreholes, Stadel-2 and Stadel-3.

The Stadel-3 borehole (Hasliboden) was started in December 2020. Just as in the Bülach borehole, the Opalinus Clay and the rocks directly surrounding it are located below the coral reef. The third borehole, Stadel-2 (Steinacker), was begun at the end of January 2021 and is located to the west of the reef.

Deep boreholes in Zürich Nordost

The Trüllikon-1 borehole is located in the south-easternmost part of the siting region where the Opalinus Clay is deepest. The borehole was completed at the end of March. Nagra was able to recover good rock samples and conduct all the planned borehole tests. There were no surprises and the results fit the picture. The composition and tightness of the Opalinus Clay are similar to those in Benken, where Nagra already drilled in the 1990s.

The second borehole in the Zürich Nordost siting region was started in Marthalen in mid-February and completed in mid-July. This borehole did not yield any unexpected results, either. With the Trüllikon and Marthalen boreholes and the earlier one in Benken, the picture of the underground in Zürich Nordost is now complete. Nagra may drill one more borehole in the siting region to clarify some questions of detail. To this end, it has prepared a drill site at Rheinau.

Deep boreholes in Jura Ost

The Bözberg-1 borehole close to Ursprung was started at the end of April and was completed in early December. The second borehole, Bözberg-2, was drilled from mid-August to mid-December in the Riedacker area. Drilling was successful in both cases and the recovered rock samples are now being investigated in more detail. In 2020, seismic measurements were conducted in the Bözberg-1 and Trüllikon (Zürich Nordost) boreholes to provide reference data for the completed 3D seismic campaign.

The previous picture of the underground was confirmed and completed. The Opalinus Clay is very tight and quietly bedded. Together with an earlier deep borehole in Riniken, Nagra has collected enough data in this siting region and does not expect to need another borehole.

An infographic on pages 16 to 17 shows the key figures for the deep borehole campaign.

Deep boreholes provide underground rock samples. To allow the drill bit to advance, the crew has to repeatedly extend the drill pipe.

Nördlich Lägern: two borehole permit applications withdrawn and a new one submitted

In February 2020, Nagra withdrew the permit applications for boreholes in Glattfelden and Weiach. Seismic investigations revealed that the northern part of the Nördlich Lägern siting region is not suitable for a repository due to the presence of fault zones. In the event that Nagra might need an additional borehole outside the reef, it submitted an application for a borehole in Bachs in October 2020. Whether this will be drilled depends on the results from the ongoing boreholes.

Covid protective measures at drill sites

Due to the Covid-19 pandemic, stricter protective measures were introduced at the drill sites early on. This was necessary as the borehole staff had alternating shifts and it was not always possible to maintain the required distance during drilling and testing procedures. Owing in part to these measures, no cases of the coronavirus were detected at the drill sites. Thanks to good personnel management and the support of the authorities, it was always possible to have the required international specialists on site.

Interim conclusion on the deep boreholes

Initial results confirm that it is possible to construct a safe deep geological repository in all three regions Jura Ost, Nördlich Lägern and Zürich Nordost. Each region has a layer of Opalinus Clay over one hundred metres thick that is very tight and quietly bedded. It also provides sufficient space for a combined repository for low-, intermediate- and high-level waste.

However, the regions also show a few differences; for example, the Opalinus Clay layer is not always located at the same depth, and the rock formations lying above and below the Opalinus Clay vary. These so-called confining geological units can also contribute to waste containment. Numerous laboratory analyses and two potential boreholes are still pending. In 2022, Nagra expects to announce the site for which it will submit a general licence application for a deep geological repository.

Keeping an eye on the drill site at night

Nagra drilling engineer Patricia Hinterholzer provides an insight into her job as “Night Drilling Supervisor”.

What are your tasks?

I monitor and coordinate the work going on at the drill site. I also make sure that the safety measures are complied with. I represent Nagra’s interests towards the drilling company, and I also take care of all drilling engineering aspects. Outside at the drilling rig, I am present at the sinking of the borehole, the recovery of drill cores and measurements in the borehole. In the adjacent office, I compile reports and plan the next work steps. I really like working through the less stressful night shift.

What skills do you need?

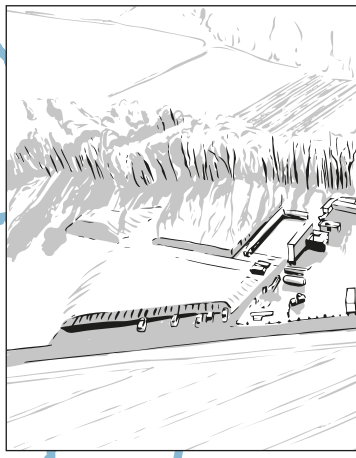
No two boreholes are the same. With every borehole, we advance our capabilities, learn from setbacks and celebrate success. Unpredictable and challenging situations arise time and again, for example, when the drilling equipment becomes stuck in the borehole or when the drilling fluid used to stabilise the borehole leaks. When these situations arise, I have to react flexibly, quickly and in a controlled manner. For all of this, I can rely on an efficient drilling team in which we all work as one.

Dieter Meyer and Patricia Hinterholzer represent Nagra’s interests at the drill site.

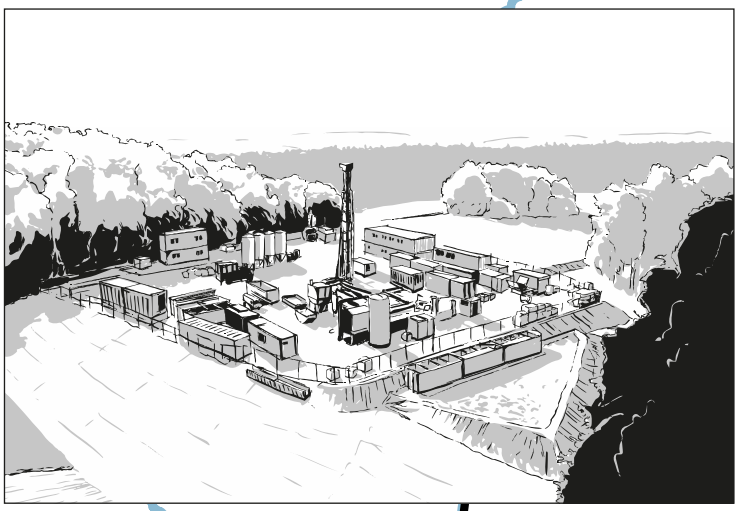
Samples from the deep boreholes are geomechanically investigated at the Swiss Federal Institute of Technology Lausanne (EPFL). With the results of these compression tests, it is possible to estimate the long-term behaviour of the Opalinus Clay when it is subjected to thermal and mechanical stresses.

Overview of the deep boreholes

Marthalen



Bözberg-2



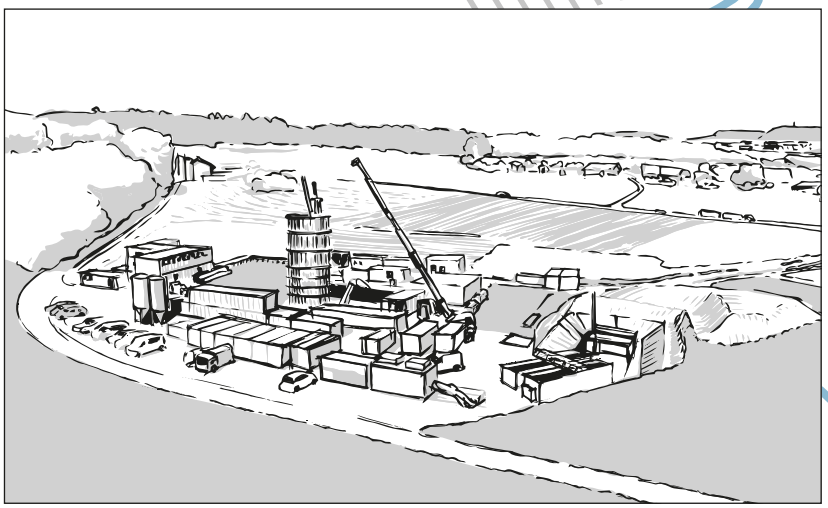
Drilling started	11th August 2020
Drilling completed	14th December 2020
Drilling duration	4 months 4 days
Final depth (m)	829
Top of Opalinus Clay layer (m)	451
Bottom of Opalinus Clay layer (m)	574
Thickness of Opalinus Clay (m)	123

Drilling started	27th April 2020
Drilling completed	2nd December 2020
Drilling duration	7 months 6 days
Final depth (m)	1037
Top of Opalinus Clay layer (m)	530
Bottom of Opalinus Clay layer (m)	651
Thickness of Opalinus Clay (m)	121

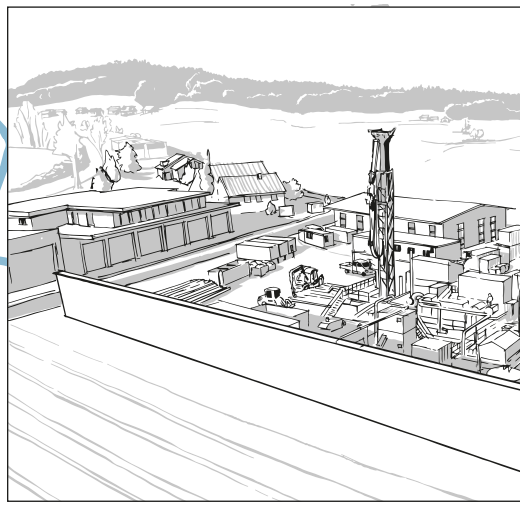
Bözberg-2

Bözberg-1

Drilling started	25th January 2021

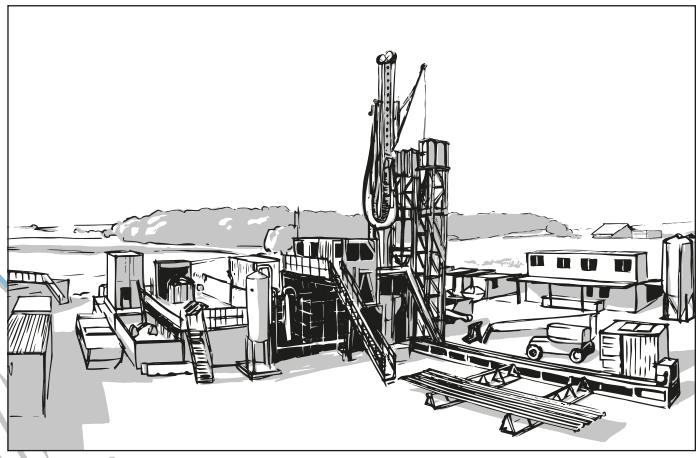


Bözberg-1



Stadel-2

Trüllikon-1



Drilling started	15th August 2019
Drilling completed	5th April 2020
Drilling duration	7 months 22 days
Final depth (m)	1310
Top of Opalinus Clay layer (m)	816
Bottom of Opalinus Clay layer (m)	928
Thickness of Opalinus Clay (m)	112

Drilling started	9th February 2020
Drilling completed	14th July 2020
Drilling duration	5 months 6 days
Final depth (m)	1099
Top of Opalinus Clay layer (m)	590
Bottom of Opalinus Clay layer (m)	705
Thickness of Opalinus Clay (m)	115

Trüllikon-1

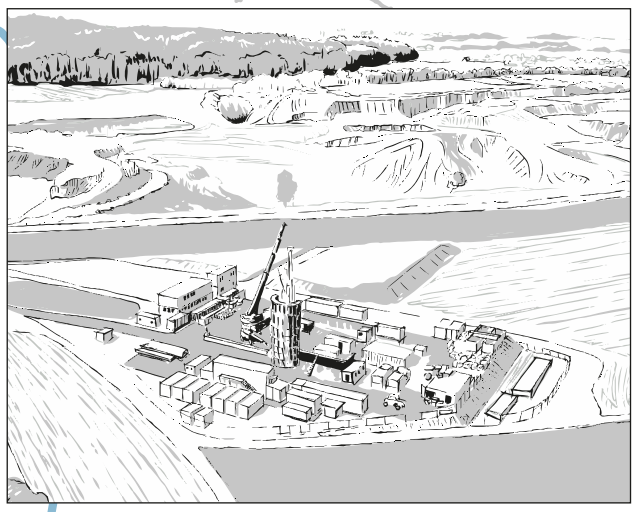
Marthalen

Stadel-3

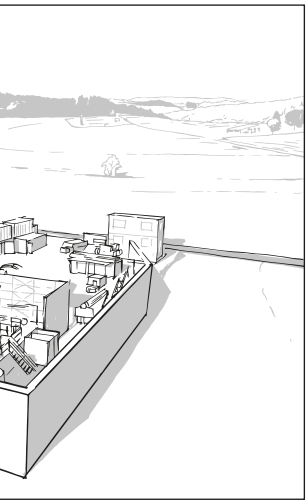
Stadel-2

Bülach

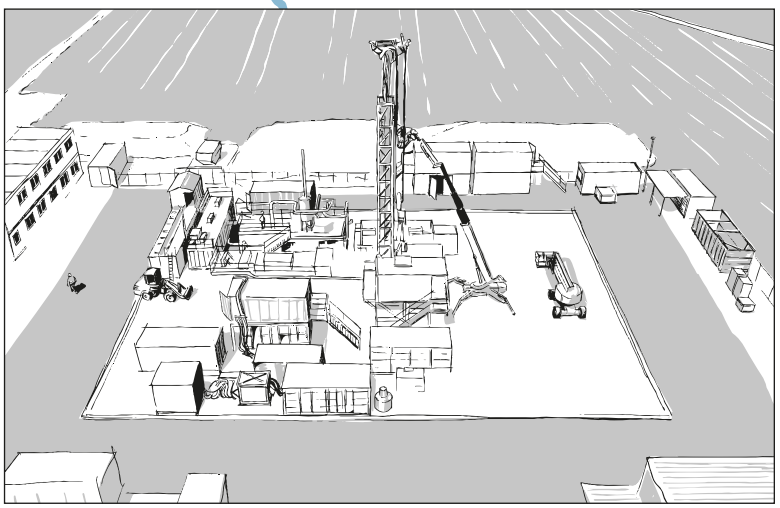
Stadel-3



Drilling started	17th December 2020
Drilling completed	-
Drilling duration	-
Final depth (m)	-
Top of Opalinus Clay layer (m)	778
Bottom of Opalinus Clay layer (m)	887
Thickness of Opalinus Clay (m)	109



Drilling started	14th April 2019
Drilling completed	27th November 2019
Drilling duration	7 months 14 days
Final depth (m)	1370
Top of Opalinus Clay layer (m)	892
Bottom of Opalinus Clay layer (m)	996
Thickness of Opalinus Clay (m)	104



Bülach

Above: The drill site of the Adlikon-Dätwil Quaternary borehole with the drilling rig. The wall protects the adjacent houses from noise.
Below: The drilling crew pulls a drill core to the surface. At this point, it is still attached to a cable in the borehole.

Quaternary boreholes completed, analyses ongoing

Nagra drilled a total of eleven Quaternary boreholes from March 2018 to December 2020. Drilling has been completed but the investigation of the rock samples continues. For every Quaternary borehole, Nagra publishes a report summarising all the measured data.

Nagra aims to learn more about the evolution of the landscape over the last approximately two million years. During this geological period, the Quaternary, glaciers advanced from the Alps into Northern Switzerland, carving troughs with a depth of several hundreds of metres into the rock. After the glaciers retreated, these troughs were filled with rock debris and then with sediments from rivers and lakes. The trough filling therefore consists of unconsolidated rocks such as gravel, sand and clay.

In 2020, Nagra drilled in the communities of Andelfingen-Niederfeld and Adlikon-Dätwil in Canton Zürich where a glacial trough runs along the present-day Thur Valley. From the surface, Nagra first drilled through a layer of unconsolidated rock over 300 metres thick and then up to ten metres into the underlying consolidated rock. Once this bedrock was reached, it was known how thick the layer of unconsolidated rock is.

High-quality drill cores obtained throughout

For investigation and characterisation purposes, Nagra recovered a total of 1800 metres of drill cores from all eleven boreholes. Obtaining good drill cores from unconsolidated rock at great depth is challenging.

The Andelfingen-Niederfeld borehole was completed in March and reached a depth of 324 metres into solid rock. The layer of unconsolidated rock is around 313.5 metres thick.

The Adlikon-Dätwil borehole reached a depth of 313 metres, and the layer of unconsolidated rock is around 303 metres thick. Towards the end of the drilling, Nagra worked around the clock to make sure that the borehole remained stable. As a result, high-quality drill cores could also be obtained from this final borehole that was concluded in early December. A barrier protected the adjacent houses from noise.

Unconsolidated rocks reveal hidden information

Nagra was able to drill into the surface of solid rock lying below the unconsolidated rock in all boreholes in the "Riniker" Field, the lower Aare Valley, the Glat Valley and the Thur Valley and now knows how deep the troughs at the drill sites are. This allows the position of the bedrock surface to be calibrated and updated based on seismic measurements. Together with data from additional, external boreholes, Nagra now has an area-wide image of the bedrock surface in the investigated regions.

Based on investigations of the drill cores, Nagra is able to say what type of unconsolidated rock fills the troughs. In the laboratory at the University of Bern, the drill cores are further investigated using chemical and geotechnical analyses. This provides Nagra with more information on the properties of the rocks and allows their age to be determined, which is a very complex task. For every Quaternary borehole, Nagra publishes a report summarising all the measured data. In 2020, reports were completed on the Trüllikon-Rudolfingen and Hochfelden-Strassberg boreholes.

Learning from the past to prepare for the future

Glacial advances will also occur in the future. For this reason, Nagra has to construct the repository deep enough to be well protected against deep glacial erosion. The results from the Quaternary boreholes help to understand erosion processes and long-term evolution and to develop scenarios of future evolution.

Aside from the Quaternary boreholes, Nagra is also investigating erosion caused by rivers cutting into the terrain. In May, it uncovered ancient fluvial deposits, so-called "Deckenschotter" ("Cover Gravels") with an excavator (see photo on page 21). To determine the age of the deposits, it looked for traces of rodent teeth and snails.

Understanding erosion processes

Over the course of millennia, erosion slowly removes the rock formations above a repository. Nagra compares the potential siting regions with regard to erosion caused by rivers and glaciers. By doing so, it learns from the past for the future.

Processes such as erosion could impair the safe containment of radioactive waste in a deep geological repository by removing the protective rock formations located above the facility. As no previously developed methodology exists to investigate erosion scenarios, Nagra developed a procedure to make statements on the impact of erosion on future landscape evolution. In 2020, it verified this procedure.

Developing methodology for erosion scenarios

Nagra is researching potential erosional evolutions using its own tailor-made methodology. The arguments have to be based on a broad scientific foundation. Two erosion-related questions are central. First: Will the repository remain deep enough to allow the geological barrier to function as long as necessary? So-called decompaction effects impair the barrier properties and can lead to an increased permeability for water and thus also for radioactive substances. These effects occur when the load on underlying rock formations decreases as a result of erosion. Second: Can deep glacial erosion lead to exposure of the waste? Mathematical models that also consider uncertainties provide answers to both questions. The scenarios included in the models are ranked with regard to likelihood of occurrence and plausibility. Aside from the depth of the repository, the models consider the erodibility of the upper rock formations, the local topography, the local uplift potential and the probability of future glaciations in the individual siting regions. Many of the input data were collected by Nagra.

With its new methodology, Nagra can now predict the probability of whether the residual cover at the investigated site will be sufficiently thick for the required time period.

Different work packages on erosion

Quaternary boreholes (see page 19) deliver valuable information for the above calculations. They contribute to an understanding of the past on which future predictions can be based. The data from the Quaternary boreholes are also used in a digital elevation model of the rock surface. This demonstrates how deep rivers and glaciers cut into the rock in the past. Aside from new information on drilling depths, the shapes of the glacial troughs that had been determined based on seismic measurements were also considered. By looking at the depths and shapes of the troughs, it is possible to evaluate whether a future glacial trough could reach the repository.

> “By looking at the depths and shapes of the troughs, it is possible to evaluate whether a future glacial trough could reach the repository.”

Climate simulations

Climate simulations on a global scale show that glaciations are to be expected in the next million years. However, the beginning of the next glaciation is strongly dependent on the predicted greenhouse gas emissions. Simulations based on current greenhouse gas emissions indicate that a minor glaciation is not expected to occur for another approximately 120 000 years. Depending on the scenario, its beginning could be shifted into the future by several 100 000 years. In 2021, Nagra will downscale the global results to a local scale to provide information on precipitation amounts and temperatures (annual averages) for the siting regions.

Glaciation

In 2020, the ice-flow models were refined and modelling studies were conducted using new climate data collected by Nagra. As modelling studies

Near Steig above Buch am Irchel (Canton Zürich), Nagra investigated the so-called "Höhere Deckenschotter" ("Upper Cover Gravels") that were deposited there by a former river. The goal was to determine the age of these deposits that lie close to the surface.

require comprehensive calculations, Nagra uses two models of varying complexity. The model based on simplified physical assumptions is used because it calculates long-term simulations more quickly and over large areas. In contrast, the more complex model considers a greater number of physical processes, which requires longer computation time. Therefore, it is suitable for simulations over shorter time periods and smaller areas. In 2020, for the first time, Nagra was able to combine the two models optimally: the latest glacial advance in the Swiss Plateau is first calculated using the simple model. Just before the siting regions are covered by glaciers, the data are passed on to the more complex model. This allows Nagra to precisely analyse the time period of several thousand years during which glaciers advanced and retreated in the siting regions.

Where to locate the encapsulation plant for high-level waste?

High-level waste has to be repackaged in an encapsulation plant. Nagra has compared the advantages and disadvantages of different sites for such a plant in a work report. Following intensive discussions on the siting issue, the regions and Cantons involved issued a joint statement at the end of 2020.

Most of Switzerland's high-level waste is held in interim storage facilities such as Zwilag in Würenlingen. Before emplacement in a deep geological repository, the waste is transferred from larger containers to smaller canisters. This takes place in an encapsulation plant that Nagra, in its reference concept, foresees as part of the surface infrastructure located at the repository site. At the end of 2018, the Federal Council decided that Nagra could also investigate locating the encapsulation plant outside the repository siting region.

Report sets out pros and cons

In 2020, Nagra compared locating an encapsulation plant at the repository site with potential variants for an external encapsulation plant at Zwilag and at four other locations. This included assessing the space requirements for the encapsulation plant as well as the use of existing infrastructure, available know-how and number of transports, etc. From Nagra's point of view, the best solution would be to locate the encapsulation plant at the repository or at Zwilag as this would result in the greatest synergies. Zwilag, for example, already operates a transloading cell for high-level waste. Moreover, unnecessary transports to new sites would be avoided. Other countries are also planning to package their high-level waste into disposal canisters at an interim storage facility or at the repository. In June, Nagra published its results in the NAB 20-14 work report, "High-level waste encapsulation plant: Advantages and disadvantages of different siting variants" (in German).

Transregional collaboration

Affected Cantons, neighbouring German districts and regional conferences were involved in the discussions on where to locate the encapsulation plant. Within the framework of transregional collaboration, the Swiss Federal Office of Energy gathered representatives from these groups for round-table discussions. In a working group on an external encapsulation plant, they compared the siting variants for the encapsulation plant at Zwilag or at the deep geological repository. The goal was to promote mutual understanding and develop a joint statement.

The working group held seven meetings between 10th June and 11th December 2020, which were moderated by Professor Michael Ambühl, Chair of Negotiation and Conflict Management at the Swiss Federal Institute of Technology Zürich (see interview). The Nagra report served as a basis for discussion in the working group, but experts from Nagra and ENSI were also consulted.

Joint statement of the working group

On 11th December, the working group compiled a joint statement on the results of the transregional collaboration outlining all the different positions. However, the members of the group did not succeed in finding a general consensus on whether locating an external encapsulation plant at Zwilag is a fundamentally better solution than locating it at the repository. In a recommendation, it called on Nagra to take full account of the positions of all actors affected by a deep geological repository in its decision on where to locate the encapsulation plant.

Explanatory film on an encapsulation plant for high-level waste (YouTube video). QR code for scanning by smartphone.

A closer look at transregional collaboration

Professor Michael Ambühl moderated the meetings of the working group on an external encapsulation plant. In this interview, he outlines how the joint statement of the members of the group was achieved and interprets the results.

Was the outcome always obvious to you?
The goal was clear: a joint statement by the working group with regard to the issue of where to locate an external encapsulation plant. To achieve this, however, we had to resolve a few methodological aspects and two fundamental issues connected to other siting options and safety. Nagra was able to demonstrate that there were no other suitable external siting options aside from the Zwilag interim storage facility and that, in principle, an encapsulation plant can be safely operated anywhere. Based on these working hypotheses, the group then carried out an evaluation of an internal versus an external site. For this purpose, we developed a criteria catalogue with the group.

"I consider the process a success."

Was it easy to evaluate the different sites for an encapsulation plant?
Initially, we proposed an evaluation model for discussion that included 15 criteria. In agreement with the working group, we reduced these down to four: burden sharing, spatial planning conflicts, synergies and transports. Following this, every delegation weighted and evaluated the external Zwilag site against an internal realisation at the repository for each individual criterion.

What do you think of the collaboration result?
The analysis exposed different interests but, in the end, a degree of consensus could be found. On the one hand, this consists of composing a statement that follows a certain structure and includes the interests of each delegation. On the other hand, the joint statement also included the agreement that, once the repository site has been selected, only the interests of those affected at that point in time would remain relevant. I therefore consider the process to be a success: the working group was able to agree on central working hypotheses that, based on this common ground, led to a constructive discussion. I am convinced that this statement will provide Nagra with a useful guideline.

ABOUT PROFESSOR M. AMBÜHL

Michael Ambühl is a Full Professor and Chair of Negotiation and Conflict Management at the Swiss Federal Institute of Technology Zürich. Prior to this, he was State Secretary for the Swiss Federal Department of Finance and the Swiss Federal Department of Foreign Affairs. On behalf of the Federal Council, the top diplomat conducted numerous negotiations including, for example, the second round of bilateral agreements with the European Union where he was the Swiss head envoy. He was also a negotiator in tax disputes with the USA and Switzerland's neighbouring countries.

Two individual repositories for radioactive waste or a combined one?

Switzerland will eventually dispose of its radioactive waste in deep geological repositories. Nagra plans to construct a repository for low- and intermediate-level waste as well as one for high-level waste, or a so-called combined repository. In 2020, it compared the advantages and disadvantages of these two variants in a report.

There are different types of radioactive waste with different properties. In Switzerland, two deep geological repositories are foreseen for the disposal of these waste types: one for low- and intermediate-level waste and one for high-level waste. These repositories can be located at two individual sites but they can also be located at the same site as a so-called combined repository. As long as safety is not compromised and there is enough available space, it is possible to construct a combined repository.

General licence requirement from the Federal Council

Nagra has to justify its proposal for a repository site in a report submitted along with the general licence application. It also has to decide beforehand whether such an application would be prepared for a combined repository or two individual repositories. The general licence specifies the site, size and approximate location of the most important structures of a deep geological repository. The decisive factor for the site selection is long-term safety. However, Nagra also has to conduct an overall evaluation considering other factors for the case where the potential sites do not differ with regard to safety.

Report compares pros and cons

In September 2020, Nagra published its NAB 19-15 work report documenting the site-independent comparison of the two variants "two individual repositories" and "combined repository". The comparison includes the environmental impact as well as topics such as space requirements, number of transports, synergy effects and operational safety.

A combined repository has advantages

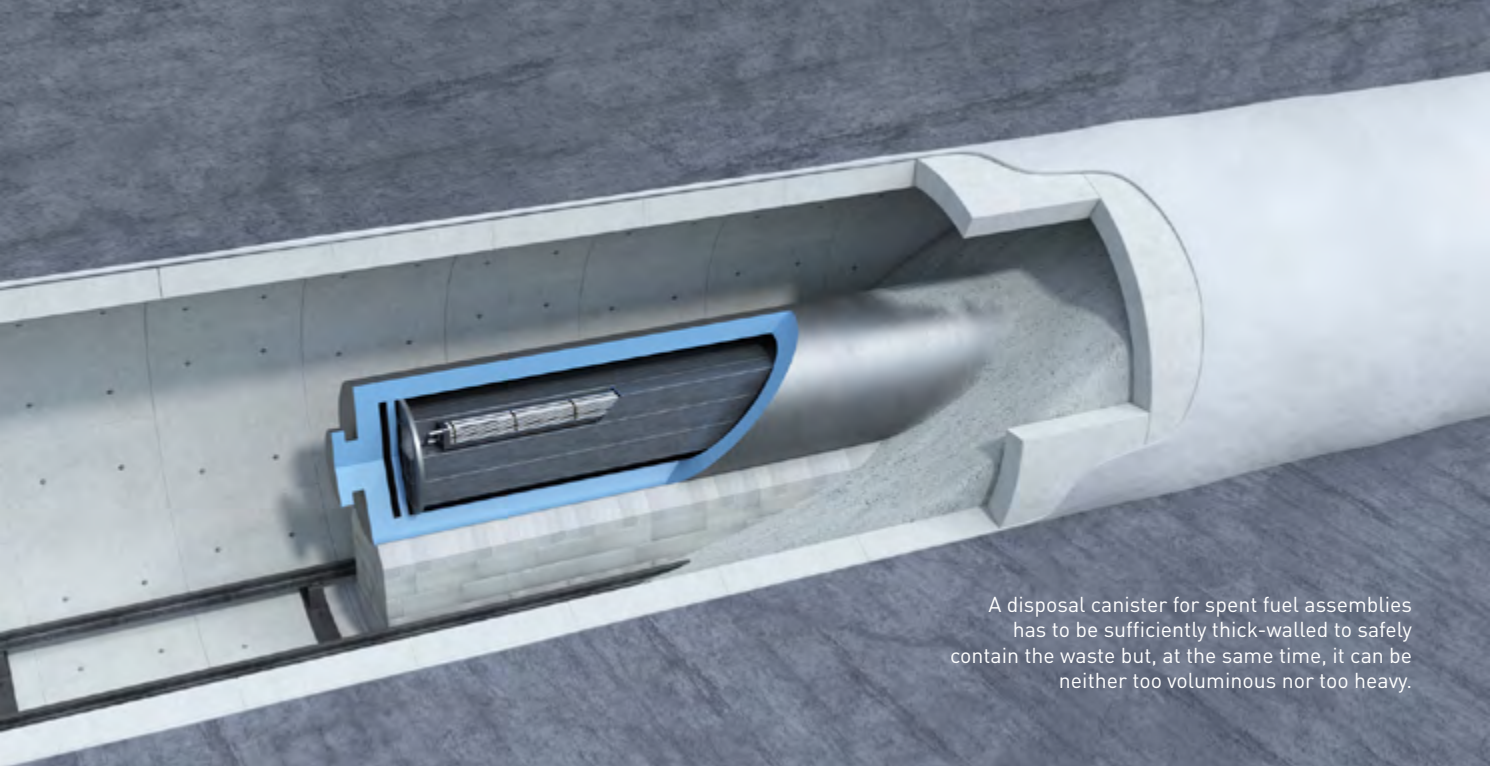
In the case of a combined repository, the ecological and socio-economic impacts are concentrated in a single siting region. However, compared to two individual repositories, the cumulative impacts are significantly lower. In addition, manpower requirements are lower in a combined repository than for two individual repositories, and the workers on site can be employed for longer operating periods.

A combined repository requires only around half the surface area that two individual repositories would take up. The lower construction volume of the surface infrastructure, the lower volume of the material excavated during construction and the lower consumption of resources and energy and CO2 emissions also point in favour of a combined repository. There are also cost benefits: a combined repository costs around CHF 1.5 billion less than two individual repositories.

In conclusion, the report shows that a combined repository has clear advantages over two individual repositories. However, a combined repository can of course only be realised if this does not impair long-term safety. Clarifying this is one of the goals for 2021.

Nagra work report NAB 19-15: "Site-independent comparison of a combined repository with two individual repositories with regard to construction and operating procedures as well as the environment" (PDF file, in German)

Marc Croket, Project Manager Repository Facilities and Operation, and his colleagues compiled the Nagra work report.



A disposal canister for spent fuel assemblies has to be sufficiently thick-walled to safely contain the waste but, at the same time, it can be neither too voluminous nor too heavy.

Practical requirements on a deep geological repository

For the planning and realisation of deep geological repositories, Nagra relies on Requirements and Configuration Management (RCM), a tool for the centralised documentation of the requirements on every component and every process of the repository. This facilitates collaboration within Nagra and allows optimisations.

A repository has to meet numerous requirements to ensure its proper functioning and the safe containment of radioactive waste. Every repository component, for example tunnels, seals, buildings, ventilation and disposal canisters, has its own requirements, but, at the same time, many of these are interdependent. A disposal canister for radioactive waste, for example, has to stay within certain dimensions so that it can be transported into the emplacement drifts, but its walls also have to be thick enough to safely contain the waste. There are also requirements on overarching topics such as long-term safety, technologies applied and procedures necessary to keep the repository running.

Maintaining an overview

To keep track of all these requirements, Nagra relies on Requirements and Configuration Management (RCM). This is an integral element of project management and can be compared to a database that stores Nagra's technical knowledge. RCM reflects the latest planning stage and is constantly updated and improved. This was also the case in 2020 when numerous documents were revised or created.

Reference material for transparent sources

By the end of 2020, a total of 90 so-called RCM sheets were available on overarching topics, processes, structures, canisters, etc. An RCM sheet defines the functions, such as those of a disposal canister, as well the requirements on the canister. To be able to understand where these requirements came from even many years later, the sheet includes the sources for each requirement (references such as legislative texts and Nagra reports). The expert responsible for each sheet is also listed.

Facilitating internal collaboration

The structured and easily accessible storage of information will significantly facilitate collaboration between different project teams within Nagra. All employees can access the information. Interfaces with other projects are visible, and open questions can be identified. As soon as the functions and requirements of a component are known, it can be further optimised. Precisely this is the long-term goal: an optimised repository project that can be successfully implemented from planning to realisation while meeting high demands and all requirements.

Two workers measuring radioactivity: the worker on the right is using a Geiger counter to check that the load inside the container has not shifted. The worker on the left is performing a wipe test to check whether the surface of the container has been contaminated.

New container for safe packaging of radioactive waste

In 2020, a new container for packaging of low- and intermediate-level radioactive waste was used for the first time. It is made of concrete and can be transported by road. It is also stackable, which facilitates handling in the interim storage facility and later in the deep geological repository.

Waste containers have to safely enclose the waste, including during transport from the nuclear power plants to the interim storage facility, in the interim storage facility and later in the deep geological repository. To optimise the space in a repository, the containers for low- and intermediate-level waste have to be stackable. The concrete containers that were previously foreseen are very heavy when filled. For this reason, Nagra developed an optimised, smaller container. It will mainly be used for low- and intermediate-level raw wastes such as structural elements made of steel or concrete from the dismantling of the nuclear power plants.

Passing very thorough tests

Before a new container is ready for use, it has to undergo several test procedures. Drop tests were already conducted on the newly developed containers in December 2019 to determine whether they can withstand significant loading without sustaining significant damage. This was important to demonstrate that the new container type complies with international standards for road transport.

Practical use during dismantling

The tests were successful and, in 2020, the first concrete containers were filled with radioactive material from the dismantling of the Mühleberg nuclear power plant and transported to the Zwilag interim storage facility in Würenlingen. They will be kept in interim storage until deep geological repositories are ready for the final disposal of the waste. Before they are disposed of in the deep geological repository, all voids in the container are backfilled with cement mortar.

Tunnel construction in Opalinus Clay: testing safe lining methods

High-level waste is disposed of in a deep geological repository or, to be more precise, in tunnels excavated into the Opalinus Clay host rock. At the Mont Terri Rock Laboratory, Nagra is investigating how these tunnels can be secured. The results will be included in the planning of the underground structures of a future repository.

Opalinus Clay is deformable, which is why constructing tunnels in this rock places higher demands on structural engineering than other rocks such as granite. To ensure that the tunnels in the Opalinus Clay remain stable over many years, they have to be secured. This is achieved by lining them using support systems. Nagra took advantage of the expansion of the Mont Terri Rock Laboratory in 2019 for the TS experiment (tunnel support system in the Opalinus Clay) and tested lining methods using steel arches and shotcrete in three tunnel sections.

Fibre-optic cables provide additional information

In the three tunnel segments, Nagra is monitoring the impact of overburden pressure on the lining segments using two methods to measure the deformations of the tunnel cross-section. The classical method is only suitable for larger deformations and is based on surveying the positions of small mirrors fastened to the tunnel walls. For the new method, Nagra uses light-transmitting fibre-optic cables that are highly sensitive and can measure minimal extensions, i.e. displacements. The cables are embedded in shotcrete or fixed to the steel arches and are run around the tunnel cross-section. The fibre-optic cables can be installed without difficulties and continue to function reliably after several months, which means that they have passed the practical test. Nagra is conducting the measurements together with its British partner organisation, RWM. Aside from Nagra, the French waste management organisation, Andra, also uses fibre-optic cables.

What are the practical benefits?

The TS experiment provides information on the behaviour of the clay rock. A constitutive model describes how Opalinus Clay behaves under mechanical stress. This allows Nagra to predict how and to what degree Opalinus Clay reacts to external impacts. This information is needed to calculate the tunnel support in a future repository. The shotcrete lining and prefabricated concrete elements have to be thick enough and sufficiently reinforced. Only then will they remain stable over the required operating lifetime. Access tunnels require the longest lifetime at around 100 years as they have to remain open until the final closure of the repository.

The constitutive model is also important for determining whether a tunnel boring machine can be used at the selected repository site. These machines

KEY EXPERIMENTS IN THE MONT TERRI ROCK LABORATORY

CI	Mineralogical interaction between claystone and cement
CI-D	Diffusion across the concrete/claystone interface
DR-B	Long-term diffusion experiment
FE	1:1 emplacement experiment for investigating the near-tunnel environment (FE) with sub-projects on gas evolution (FE-G) and monitoring (FE-M)
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
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

Deformations in the tunnel lining are determined based on the classical method: a surveying device is used to measure the distance from the device to the mirrors attached to the tunnel walls. The distance is then compared with earlier measurements.

expedite tunnel construction, however, under unfavourable conditions, they can become stuck in the rock, which would result in cost increases and delays.

Conditions differ from site to site

Nagra is currently examining suitable constitutive models. For calculations based on such models, parameters are required that characterise the Opalinus Clay. Its properties at the Mont Terri Rock Laboratory, however, vary slightly from those in the siting regions. This is considered by using different parameters that are determined in rock-mechanical laboratory experiments. Nagra has already conducted many experiments on drill cores obtained at the rock laboratory. In 2021, it will assess whether the results of the TS experiment can be reproduced based on the constitutive model and the parameters.

In 2020, Nagra also carried out rock-mechanical tests on drill cores recovered from the deep boreholes. This allows parameters to be obtained for the Opalinus Clay in each of the potential siting regions. Together with the corresponding parameters and the constitutive model, Nagra can plan the layout of the underground repository facilities at the selected site.

Large-scale experiment: why is Nagra heating a tunnel inside a mountain?

Nagra has been researching the safe deep geological disposal of radioactive waste for decades. In 2020, it started the long-term HotBENT experiment at the Grimsel Test Site to investigate how warm a repository tunnel for high-level waste can eventually become. The resulting knowledge will help to optimise the repositories.

The HotBENT experiment is about bentonite. Nagra uses bentonite to seal the tunnels in which the high-level waste will be emplaced: its purpose is to tightly backfill the voids between the disposal canisters and the tunnel wall. It is one of several safety barriers that enclose the waste in the repository. Bentonite consists of clay minerals, has a very low hydraulic permeability and swells upon contact with moisture. In the repository, the high-level waste generates heat that is released in the emplacement tunnel. In the experiment, this heat is simulated with the aid of heaters.

Turning up the heat on bentonite

In HotBENT, the bentonite is exposed to temperatures ranging from 175 to 200 degrees Celsius. This is considerably higher than in previous experiments. When bentonite becomes too warm, it might no longer be able to provide optimum containment of the waste. Nagra aims to use HotBENT to determine what temperatures bentonite can safely withstand and what happens when those temperatures are exceeded.

20-year heating period

Starting in spring 2020, Nagra has extended a tunnel to create space for four heaters (see illustration on the right). In October, the first heater was installed and then backfilled with granular bentonite material. The second heater was emplaced in December. After this was backfilled, construction started on the intermediate sealing section that divides the experiment into two sections. The heaters installed so far will run for up to 20 years, and the measurement sensors in this section of the tunnel are already gathering data.

In early summer 2021, two additional heaters will be emplaced and backfilled. These are only scheduled to run for five years and will then be dismantled. HotBENT will complement existing knowledge on bentonite and contribute to the safety of a future deep geological repository. Aside from Nagra, eight other international partner organisations are participating in this experiment.

Two questions for Florian Kober Project Manager of HotBENT

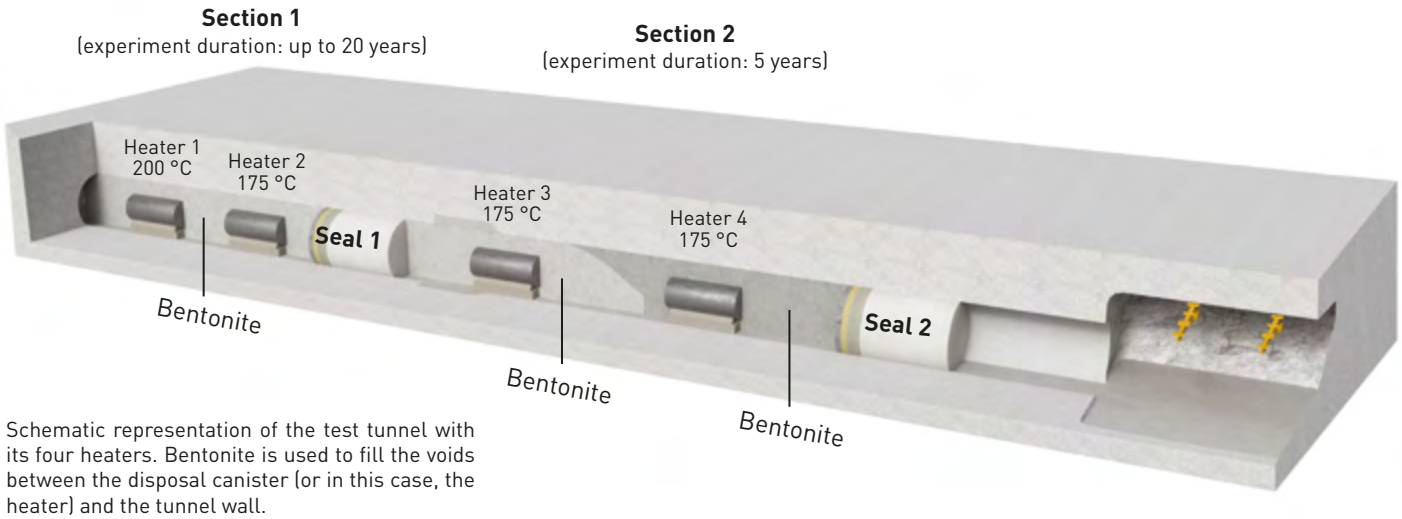
What benefit does Nagra hope to gain from this experiment?

HotBENT is a very important experiment for Nagra. If the bentonite can withstand higher temperatures than previously assumed and still meet all safety requirements, it will be possible to optimise the deep geological repository. The disposal canisters, for example, could be moved closer together, which would reduce the space requirements for the repository. This, in turn, would reduce the costs.

How did HotBENT progress under the coronavirus?

The year was a very challenging one, and not only due to the coronavirus. However, I am satisfied with our progress. To enter the Grimsel Test Site, we use the same access as the Oberhasli hydropower plant does to reach its facilities. Both were carrying out construction work and had to get around each other, which required meticulous planning. In addition, the early onset of winter hampered the delivery of material needed for the experiment.

The tunnel with the heater is already largely backfilled with granular bentonite material.



Schematic representation of the test tunnel with its four heaters. Bentonite is used to fill the voids between the disposal canister (or in this case, the heater) and the tunnel wall.

MAJOR EXPERIMENTS AT THE GRIMSEL TEST SITE

CFM	Formation and migration of colloids and their influence on the mobility of radionuclides	**ISC**	Controlled hydraulic stimulation of existing fault zones; experiment run by the Swiss Competence Center for Energy Research – Supply of Electricity
CFM i-BET	In-situ bentonite erosion test	**LASMO**	Monitoring and characterisation of the geosphere
CIM	Testing the transport properties of C-14 and I-129 through cement barriers	**LTD**	Long-term diffusion of radionuclides
GAST	Gas-permeable seal test: gas-permeable tunnel seals for a L/ILW repository under realistic conditions and on a realistic scale	**MaCoTe**	Corrosion experiments with components of the engineered barriers
HotBENT	Investigation of the safety function of bentonite barriers exposed to elevated temperatures	**Plug experiment**	Engineering studies and demonstration experiments on repository design

Digital portraits in an online exchange of expertise: the Grimsel Test Site's partner organisations at the annual "meeting" of the International Steering Committee (ISCO) in early June 2020.

International collaboration

Nagra is involved in many international projects and organisations. This also includes the IGD-TP Technology Platform that coordinates activities on planning and realising deep geological repositories in Europe. Nagra remained chair in 2020.

The "Implementing Geological Disposal of Radioactive Waste Technology Platform" (IGD-TP) unites all major European waste management organisations, including those from Belgium, Finland, France, Sweden and Switzerland. In a few years, the first deep geological repositories for spent fuel assemblies and high-level waste will begin operating, thus realising one of the IGD-TP's main founding purposes. For this reason, the Platform developed a new vision in 2019: to industrialise deep geological disposal of radioactive waste in Europe by 2040. The first deep geological repositories have to be operated safely. The initial practical experience drawn from these will later benefit other organisations such as Nagra. In addition, the entire disposal process, from planning through construction to operation of the repositories, is to be optimised.

Focus on construction and operation

Irina Gaus, Nagra's Head of Research & Development (R&D), chairs the IGD-TP and heads the secretariat. Despite the pandemic, 2020 was a busy year. Together with the member waste management organisations, decisions were made on how to implement the IGD-TP's new vision and where to place R&D priorities. Jointly planned projects were also documented in the strategic research agenda. Many countries have sound projects, and the focus is increasingly shifting to topics concerning the construction and safe operation of a deep geological repository. The aim of the research agenda is to help ensure that the involvement of the member organisations in the "European Joint Programme on Radioactive Waste Management" (EURAD) project of the European Union is goal-oriented and serves the interests of the Platform.

Safety of a deep geological repository is key

For deep geological disposal, numerous research and development topics are investigated. Some of these require an intensive exchange of experience and know-how with other countries. At the beginning of February 2020, for example, Nagra and its British partner organisation, RWM, conducted a workshop on the topic of the post-closure safety of a deep geological repository. Even after a long time period or under unfavourable conditions, the uncon-

trolled release of radioactivity in a repository has to be avoided. This so-called criticality safety has to be demonstrated. Representatives from different waste management organisations openly shared the legal provisions and the latest state of the art in their countries. For future collaboration, they identified questions and aspects concerning everyone involved. They also discussed a joint argumentation for the demonstration of criticality safety. It is also important that the results from the individual countries do not contradict one another or, if they do, that deviations can be well justified.

Know-how exchange beyond IGD-TP

Waste management organisations also work together beyond the scope of this platform. Nagra and its Belgian partner organisation, ONDRAF/NIRAS, are involved in experiments being conducted in the Canadian research centre, Canmet. The focus of this research is on the corrosion of metals in a deep geological repository once oxygen has been depleted, resulting in the formation of hydrogen gas. The goal is to improve the understanding of corrosion rates, corrosion mechanisms and gas formation rates in environments containing cement and bentonite, which typically exist in a deep geological repository. To measure the extremely low corrosion rates, Canmet has developed a method and special instruments for corrosion experiments on copper and carbon steel. In 2020, this method and the measurement results were presented in scientific publications and at a workshop in France.

Three questions for Irina Gaus, Chair of the IGD-TP

What are your tasks as Chair?

I try to reconcile the interests of all the waste management organisations. What makes this challenging is that the waste management projects in the individual countries are at varying stages of development. Together, we agree on research and development topics that are suitable for international collaboration. We have documented our common goals in the Vision 2040 and in the strategic research agenda. I also represent the interests of the IGD-TP towards those outside our platform and create acceptance for our work.

In which areas does Nagra benefit most?

Nagra gains most from projects that are at a very advanced stage. Our French sister organisation, Andra, will soon submit a construction licence application for its deep geological repository. In many aspects, we share the same interests as both countries will construct their repositories in clay rock. In the past, Andra was able to benefit from Nagra with regard to clay research, and now we can learn how Andra will put theory into practice, especially in the field of materials technology. Sweden and Finland have already submitted their construction applications, but they are pursuing different concepts. However, an area where we share common interests is, for example, the engineered safety barriers: we also use bentonite and collaborate closely in several projects.

Where can Nagra contribute its knowledge and experience?

Nagra has a unique knowledge of clay rocks. In addition, together with the Paul Scherrer Institute, we performed pioneering work in the field of radionuclide migration, in which we invested 20 to 30 years of intensive research. Many waste management organisations apply our knowledge in their programmes. Nagra has also placed itself in the front line of research with regard to the impact of gas on a deep geological repository, drawing from solid knowledge based on experiments and modelling studies. Other waste management organisations benefit from this because we publish our R&D results, thus sharing them with the scientific community.

Nagra shares its expertise with its partners

Nagra has a wealth of experience and expertise in logistical and technical fields. Its partners can benefit from this in the form of consultation services. Learn more about knowledge transfer and collaborative partnerships.

Nagra supports partner organisations in areas such as strategic programme planning, specification of waste inventories, site selection, site characterisation and site evaluation, repository conceptual design, safety case development and safety analyses, public outreach and training.

Sealing boreholes

For over six years, Nagra has been supporting the British waste management organisation, RWM, in a project on sealing of deep exploratory boreholes. Currently, Nagra is heading the development of a prototype of a so-called "bridge plug" made of metal. These plugs form part of the sealing concept for boreholes where they seal sections or separate different sealing materials from one another. Their purpose is to prevent the longitudinal flow of gases and liquids in a borehole.

Since 2018, Nagra has been conducting investigations together with the Friedrich Alexander University (FAU) in Erlangen, Germany. Studies have shown that copper-based alloys are the most promising and these were therefore selected for laboratory experiments and the plug prototype.

In sedimentary rocks such as Opalinus Clay, the borehole wall is not uniform but uneven, and sealing it can be challenging with regard to ductility and the shape of the plug. Nagra is currently developing a procedure with RWM for placing the plugs into the boreholes as efficiently as possible. As of 2020, Nagra's Japanese partner organisation, NUMO, is also participating in this subproject.

Know-how for geothermal projects

Nagra contributes its extensive geoscientific know-how to planning and carrying out seismic investigations and deep boreholes and to analysing and interpreting the measurement results. Nagra collaborates with external partners to further develop the use of geothermal energy.

In 2020, Nagra provided support in the "Bedretto Underground Laboratory for Geosciences and Geoenergies" (Canton Ticino). This laboratory is being set up by the Swiss Federal Institute of Technology Zürich within the framework of the "Swiss Competence Center for Energy Research – Supply of Electricity" (SCCER-SoE) initiative. Experiments are being carried out on hydraulic fracturing, which involves making solid rock permeable by injecting it with water. The fractures that form and connect in the rock form a heat exchanger, based on which various aspects that are important with regard to geothermal energy are investigated. Nagra provided support in setting up and anchoring measurement and monitoring devices in the observation boreholes. After careful planning, it cemented and sealed the boreholes.

In the Basel region, a 3D seismic campaign is planned to investigate the underground in preparation for additional geothermal boreholes. In 2020, Nagra collaborated on the planning and optimisation of the campaign. In a detailed study, it concretised the region under investigation and defined the parameters, based on which the 3D seismic campaign will be conducted.

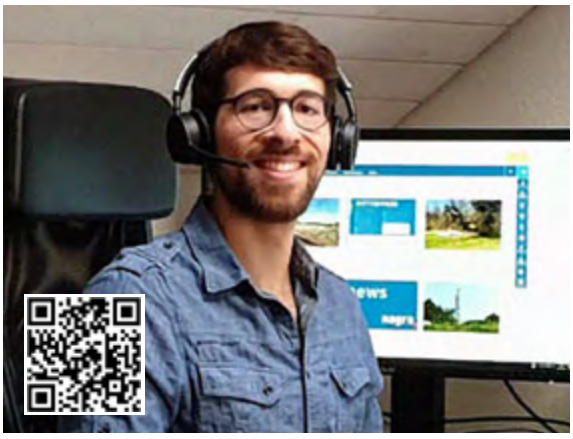
At the Karlsruhe Institute of Technology (KIT) in Germany, a research project involves the introduction and storage of heat in deep groundwater aquifers. Nagra won a bid to plan two deep boreholes in combination with the scientific investigation of the deeper underground.

Above: Different bridge plug prototypes are inserted into a borehole where they prevent the longitudinal flow of gases and liquids.

This equipment was set up in the "Bedretto Underground Laboratory for Geosciences and Geoenergies" of the Swiss Federal Institute of Technology Zürich. Nagra used it to cement the observation boreholes after the measurement and monitoring devices were installed.

Watch our videos on YouTube

On YouTube, you can learn more about the topics that Nagra focused on in 2020: deep boreholes, Quaternary boreholes and dialogue with the public. The colleagues filmed in these German-language videos give Nagra a face. Simply use your smartphone to scan the QR codes, and – "action"!



Open day at Bözberg-2

At the open day at the Bözberg-2 deep borehole, the public was invited to take a look at what Nagra does. In this video, Felix Glauser, Deputy Head of the Media Office, captured the voices of different visitors.

Nagra's Quaternary boreholes

Herfried Madritsch, Section Head Geology & Geophysics, looks back on the completed Quaternary borehole campaign. His colleague, Gaudenz Deplazes, Project Manager Geology, tells you what happens to the rock samples next.

Visiting a drill site

Learn more about the deep boreholes from Philipp Senn, Deputy Head Collaboration Sectoral Plan and Public Outreach. He will take you for a tour of a drill site and show you how many interesting facts you can discover.

We are Nagra

If you would like to learn more about the people working for Nagra, watch this video. You can accompany Lukas Oesch, Project Manager Regional Participation, during one of his working days and during his leisure time.

Public outreach

Severely restricted events

Of the 13 regional trade fairs and markets in which Nagra had planned to participate, restrictions caused by the coronavirus led to the stand being set up only once – at the late-summer market in Eglisau (12th September). Visitors were invited to take a hammer to fragments of fossil-rich Posidonia Shale under the guidance of a staff member. All other events had to be cancelled.

Due to a good safety concept, conducting guided tours at Nagra's drill sites remained possible overall. Most of the visitors live in the immediate vicinity of the drill site. Overall, 860 visitors (in 84 groups) came to obtain information on the Trüllikon, Marthalen, Bözberg-1 and Bözberg-2 deep boreholes.

Special experience in an underground rock laboratory

At the Grimsel Test Site (Canton Bern) and Mont Terri Rock Laboratory (Canton Jura), it is possible to observe research on radioactive waste disposal being conducted under realistic conditions. Due to the coronavirus, restrictions had to be applied, but guided tours remained popular in 2020. Last year, 149 people (20 groups) visited the Grimsel Test Site, and 1002 people (72 groups) visited the Mont Terri Rock Laboratory. Unfortunately, eight visitor days for selected groups had to be cancelled.

Electronic media

The web pages on the individual drill sites are continuously updated with the latest information. Numerous contributions, including photos and videos, document the ongoing deep boreholes and the Quaternary borehole campaign completed in 2020. Drone footage of the drill sites was very popular.

In 2020, Nagra relaunched its electronic newsletter. Three newsletters were sent to 4100 German-speaking and 290 French-speaking recipients. At 50%, the opening rate was above average. A newsletter for teachers was sent out in March.

In 2020, different internal workshops were conducted to prepare for the relaunching of Nagra's website. Discussions focused on target groups, the new vision and user personas. In addition, Nagra conducted two user surveys of its website as well as an external usability test in a laboratory. The results of these will be included in the future content strategy.

Print products

In October 2020, a factsheet was published with more detailed information on a potential deep borehole in Bachs. In addition, Nagra published a leaflet on the retrievability of radioactive waste as well as a flyer on the Grimsel Test Site providing visitor information.

In touch with the media

In 2020, the media office was intensely involved with the deep borehole campaign. Due to the coronavirus, events took place online but met with a greater response than in earlier years. The highlight was a media conference in early November on the preliminary results of the deep borehole campaign featuring a live broadcast from the storage facility in Döttingen where hundreds of drill cores from the Bülach borehole were exhibited. This resulted in a report in the TV programme "Schweiz aktuell" (Switzerland Today) as well as coverage in all major print media and several radio programmes. Over 120 articles were published following the media conference. Ten additional media releases provided public information.

Digitalisation in the school & youth sector

The coronavirus made it difficult to hold exchanges with the younger generation as numerous school events and drill-site excursions and workshops had to be cancelled. Still, close to 300 young people showed an interest in the topic of radioactive waste. At the first digital TecDay in December, almost 100 students visited our module "Radioactive waste: is there a "forever" solution?".

Collaboration with the regions

Regional collaboration requires not only geologists and engineers but also knowledgeable people who stay in touch with the population of a potential siting region. Nagra openly informs residents, communities and members of the regional conferences about its work.

Taking Nagra's pulse

Closely following geoscientific investigations and talking to experts and the responsible project managers – this is "Nagra live". Members of the working groups on safety of the Jura Ost, Nördlich Lägern and Zürich Nordost regional conferences were able to obtain an on-site impression of the journey of rock samples, starting with their recovery at the drill site, followed by laboratory analysis and, finally, data analysis.

Four members of the working groups accompanied the launching of "Nagra live" at the Bülach borehole when drill cores were recovered from the underground. Later, they visited the Institute of Geological Sciences of the University of Bern, where researchers showed them how rock samples obtained from Nagra's deep boreholes and Quaternary boreholes are analysed. Following this excursion, Gabriela Winkler, co-chair of the working group on safety of the Nördlich Lägern regional conference, said: "During my visits to the deep borehole in Bülach and here in Bern, I obtained a deep insight into the topic, and I can now appreciate the complexity and extent of the investigations."

In early 2020, members of the working groups visited Nagra's head office in Wettingen. The project managers responsible explained how scientific projects are planned and the reasons behind specific approaches to data analysis. In November, the group visited a storage facility showing drill cores recovered from the Bülach borehole.

The members of the working groups also asked critical questions about the coral reef and the composition of the Opalinus Clay. Experts used drill cores to explain why the coral reef encountered in the Bülach borehole is tight and showed that the Opalinus Clay layer has a homogeneous composition.

A special thanks to the affected residents

The Adlikon-Dätwil Quaternary borehole in Canton Zürich was the eleventh and final borehole of this large investigation campaign (see page 19). Nagra would not have been able to conduct these investigations without the support of the affected communities, rural development cooperatives, property owners, land managers and farmers.

Depending on the circumstances, a Quaternary borehole requires an area of 600 to 1300 square metres in a field or forest. Large lorries also had to be able to access the site, and it could not be taken for granted that the affected residents agreed to this. Talks with the community authorities and private individuals had to be conducted at an early stage. In one case, the residents received a flyer inviting them to attend an information event on site where open questions were clarified with everyone present. The local authorities were very helpful in facilitating field work, and the residents proved to be understanding, for both of which Nagra is very grateful.

Philip Birkhäuser, Section Head Collaboration

COMMUNITY NEWSPAPERS ARE AN IMPORTANT SOURCE OF INFORMATION

"Whenever possible, we thanked the population in the community newspapers after each Quaternary borehole. In this way, even those not directly involved gained some insight into the background of our field work. We want to report as transparently as possible and hope that this will enable the local population to understand why we were active in their community. We regularly use community newspapers or flyers to provide information on ongoing deep boreholes."

Editor Saskia Haueisen with an issue of the Untersiggenthal town newspaper "Schlüssel" in which Olivier Moser, Nagra's Project Manager Regional Collaboration for the Jura Ost region, was allowed to publish an article.

Below: Fitted out in full personal protective equipment and guided by an expert, the members of the Nördlich Lägern working group on safety visited the Bülach drill site. From left to right: Michael Gysi (Project Manager Drill Site Geology, Nagra), Markus Zink, Gabriela Winkler, Felix Meier, Rolf Glaus and Lukas Oesch (Nagra's Project Manager Regional Participation for the Nördlich Lägern region).

Board of Directors

Corina Eichenberger
President of the Board of Directors

Dr. Willibald Kohlpaintner
Vice President
Axpo Power AG

Dr. Philipp Hänggi
BKW Energie AG

Dr. Thomas Kohler
Alpiq AG

Roland Grüter
Kernkraftwerk Leibstadt AG

Professor Lino Guzzella
Swiss Federal Institute of Technology Zürich

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 a closed meeting on the safety-based comparison in 2020. The main focus of all meetings was on supporting the Sectoral Plan process. The Board of Directors also took note of the planned research and development projects for 2021 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 2019, the budget for 2021 and the accumulated accounts. The annual general meeting of the members of the Nagra Cooperative was held on 30th June 2020. The members approved the annual report and accounts for 2019. In December 2020, Professor Lino Guzzella was elected as an additional member of Nagra's Board of Directors.

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
Würenlingen

Technical Committee
Dr. Thomas Kohler
Chairman
Alpiq AG

Finance Commission
Urs Helfer
Chairman
Axpo Power AG

Commission for Communication and Information
Dr. Thierry Strässle
Chairman
Swiss Confederation

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

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

Dr. Severin Wälchli (from 1st July 2020)
Division Head Planning & Construction of Deep Geological Repositories

Further members of the Nagra management team

Dr. Irina Gaus
Head of Research & Development

Armin Murer (until 31st August 2020)
Deputy Division Head Collaboration
Sectoral Plan & Public Outreach

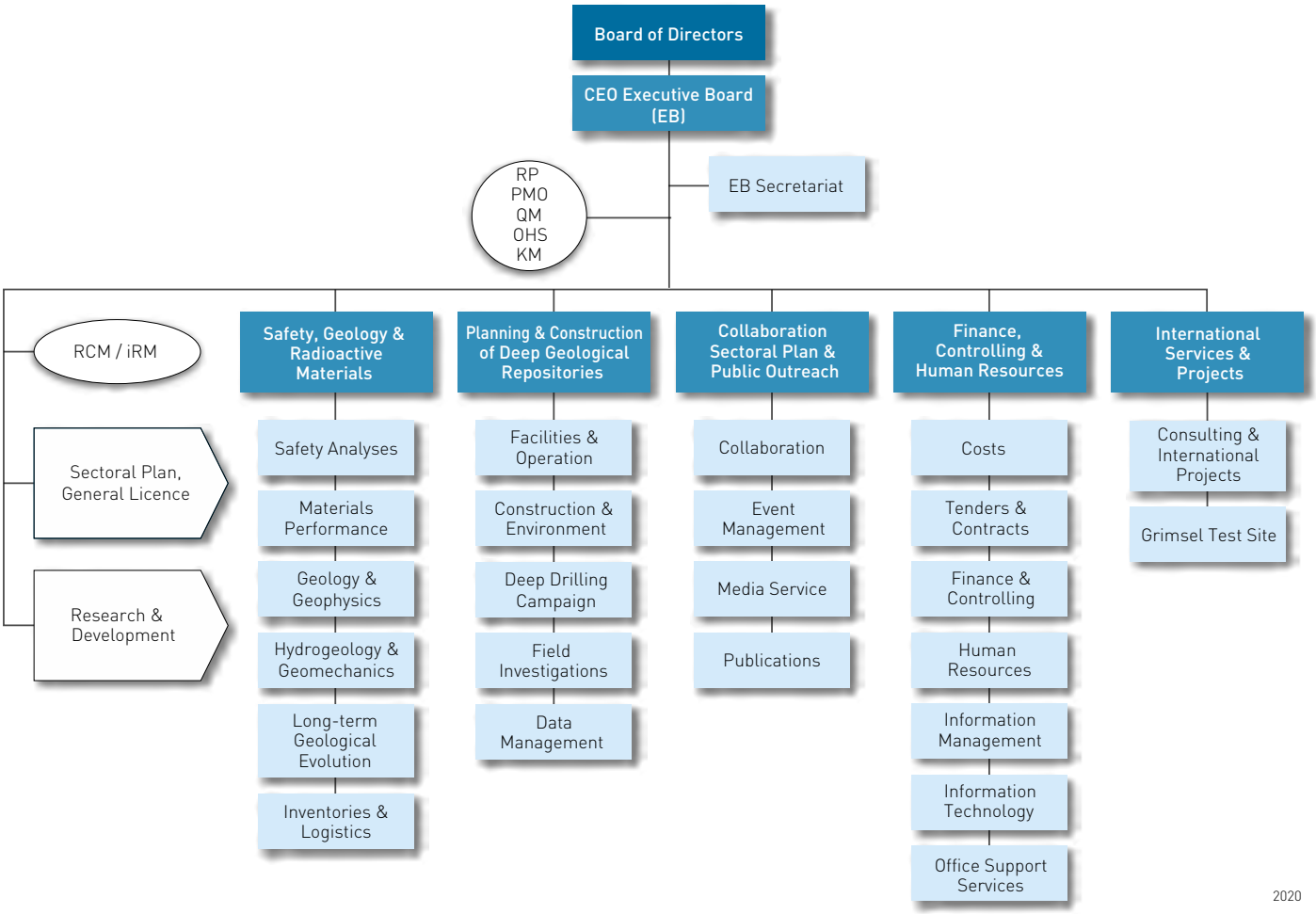
Dr. André M. Scheidegger
Deputy Coordinator Major Project
Sectoral Plan Stage 3

Dr. Stratis Vomvoris
Division Head International Services
and Projects

Executive Board

Nagra's Board of Directors has elected Dr. Severin Wälchli as new Division Head Planning & Construction of Deep Geological Repositories and Member of the Executive Board as of 1st July 2020. At the end of the year, Nagra's Board of Directors appointed Dr. Matthias Braun as its new CEO. The 52-year-old Swiss citizen will join Nagra on 1st March 2021 and assume operational responsibility on 1st May 2021. Braun has a doctorate in geology and will succeed Dr. Thomas Ernst, who will retire after 14 years as CEO.

Organigram of the head office



RP: Radiation Protection
PMO: Project Management Office
QM: Quality Management
OHS: Occupational Health and Safety
KM: Knowledge Management
RCM: Requirements and Configuration Management
iRM: integrated Risk Management

Head office

At the end of 2020, Nagra had 133 employees excluding interns (120 permanent employees and 13 temporary employees). Together, they filled 118 full-time positions.

ARMIN MURER

Nagra Management Team Member Armin Murer retired at the end of August 2020. In 1999, the former member of the Cantonal Parliament of Nidwalden and construction engineer for the Cooperative for Nuclear Waste Management Wellenberg took up the position of Project Manager for the "Exploratory Tunnel Wellenberg". In early 2004, he joined Nagra as Head of Public Outreach.

Armin Murer advocated transparent and open dialogue with the public, politicians and the authorities. He was substantially involved in Nagra's development and realisation of attractive public programmes, including road shows and the highly popular trade fair exhibitions "Time Ride" and "Journey through Time to a Deep Repository". Under his leadership, guided tours of the underground rock laboratories for the public were expanded. He was also involved in the construction of the new visitor centre at the Mont Terri Rock Laboratory. Until his retirement, he represented Nagra in different committees and working groups.

Armin Murer gave Nagra "a face". He gladly and competently committed himself to the organisation and its important environmental task. Thanks to an extraordinarily wide public and political network, he and his team managed to make interested members of the public aware of Nagra's mission of deep geological disposal.

Annual financial statements 2020

Comments on the annual financial statements 2020

The current financial statements for 2020 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 (Articles 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.

Operating income increased by CHF 24.6 million compared to the previous year, which is primarily due to the continuation of the deep borehole campaign launched in 2019. In 2020, boreholes were drilled in Marthalen, Bözberg-1 and Bözberg-2, and preparations were made for the Stadel-2 and Stadel-3 boreholes.

Mainly as a result of increased collaboration in international projects, the net proceeds from sales of goods and services increased by CHF 2.6 million. Other operational costs, depreciation and the financial result are comparable to those of the previous year.

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

Wettingen, 11th March 2021

Dr. Thomas Ernst, CEO

Income statement

Note		1.1.–31.12.2020 CHF	1.1.–31.12.2019 CHF
C1	**Net proceeds from sales of goods and services**		
	Net proceeds from services for third parties	5 124 339	2 412 276
	Research contributions from third parties	119 473	237 581
	Net proceeds from services for Cooperative members	376 785	365 414
	Total net proceeds from sales of goods and services	**5 620 598**	**3 015 271**
C2	**Contributions of members of the Cooperative**		
	Contributions to administration costs	700 000	700 000
	Contributions to project expenditure	113 677 911	91 749 748
	Total contributions of members of the Cooperative	**114 377 911**	**92 449 748**
	Other operating income	**284 764**	**187 674**
	Operating income (total output)	**120 283 273**	**95 652 693**
C3	Cost of materials (project expenditure)	96 222 557	72 052 823
C4	Staff costs	20 781 179	20 379 311
C5	Other operational costs	2 839 242	2 874 193
C10	Depreciation and value adjustments on fixed assets	238 797	202 455
	Operating result	**201 498**	**143 911**
	Financial income	–72 439	–214 935
	Financial costs	146 249	229 204
	Ordinary result	**127 688**	**129 642**
	Extraordinary, non-recurring or prior-period expenditure	–	–
	Annual profit before taxes	**127 688**	**129 642**
	Direct taxes	127 688	129 642
	Annual result	**–**	**–**

Explanations pages 52-56

Balance sheet

Note	Assets	31.12.2020 CHF	31.12.2019 CHF
	Current assets		
	Cash and cash equivalents	26 532 321	16 530 924
C6	Trade receivables	806 985	894 803
	Due from third parties	598 476	698 278
	Due from members of the Cooperative	208 509	196 525
C7	Other current receivables	864 701	1 227 873
	Towards third parties	864 701	1 227 873
C8	Non-invoiced services	2 569 929	2 285 870
C9	Accrued income and prepaid expenses	455 300	942 763
	Total current assets	**31 229 236**	**21 882 233**
	Capital assets		
C10	Tangible fixed assets	1 632 494	1 566 408
	Total capital assets	**1 632 494**	**1 566 408**
	Total assets	**32 861 730**	**23 448 641**
	Equity and liabilities		
	Current borrowed capital		
C11	Trade payables	7 398 082	6 719 568
	Due to third parties	7 379 742	6 394 386
	Due to members of the Cooperative	18 340	325 182
	Other current liabilities	1 509 322	735 725
	Due to third parties	1 509 322	735 725
C12	Advance payments received	3 848 689	3 504 946
C13	Deferred income and accrued expenses	19 965 637	12 348 402
	Total current borrowed capital	**32 721 730**	**23 308 641**
	Total liabilities	**32 721 730**	**23 308 641**
C14	**Equity**		
	Cooperative capital	140 000	140 000
	Annual result	–	–
	Total equity	**140 000**	**140 000**
	Total equity and liabilities	**32 861 730**	**23 448 641**

Explanations pages 52-56

Cash flow statement

Note		1.1.–31.12.2020 CHF	1.1.–31.12.2019 CHF
	Annual result	–	–
C10	Depreciation and value adjustments on fixed asset items	238 797	202 455
	Change in net current assets		
C6	Decrease (+) / increase (–) trade receivables	87 818	–447 871
C7	Decrease (+) / increase (–) other current receivables	363 173	–1 055 533
C8	Decrease (+) / increase (–) non-invoiced services	–284 059	–281 265
C9	Decrease (+) / increase (–) prepaid expenses	487 462	–562 806
C11	Decrease (–) / increase (+) trade payables	678 513	–208 109
	Decrease (–) / increase (+) other current liabilities	773 597	–1 034 319
C12	Decrease (–) / increase (+) advance payments received	343 743	1 738 488
C13	Decrease (–) / increase (+) deferred income and accrued expenses	7 617 235	389 762
	Cash flow from operating activities	**10 306 280**	**–1 259 199**
C10	Investments in fixed assets	–304 883	–238 522
	Cash flow from investment activities	**–304 883**	**–238 522**
	Cash flow from financing activities	**–**	**–**
	Change in cash and cash equivalents	**10 001 397**	**–1 497 721**

Change in cash and cash equivalents	**2020**	**2019**
Cash and cash equivalents as of 1st January	16 530 924	18 028 645
Cash and cash equivalents as of 31st December	26 532 321	16 530 924
Net increase/decrease in cash and cash equivalents	**10 001 397**	**–1 497 721**

Explanations pages 52-56

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 (Articles 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, Switzerland

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 11th March 2021 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 on the annual financial statements

C1) Net proceeds from sales of goods and services
Successful international projects led to a significant increase in the proceeds from services for third parties. Proceeds from NPP operators were comparable to those of the previous year, and 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 has an annual result of CHF 0.

The new cost distribution between the NPP operators and the Swiss Confederation went into force as of 1st January 2020. This addendum on the agreement on the financing of Nagra, in accordance with the decision of the extraordinary general meeting held on 30th June 2020, resulted in a compensation payment by the Federal Government to the involved parties of CHF 137.2 million (incl. interest, excl. VAT). The balance for Nagra is zero, which is why the individual positions are not listed in the financial statement for 2020.

C3) Cost of materials (project expenditure)

The project expenditure is made up as follows:

Project-related external services for:	**2020**	**2019**
	CHFk	CHFk
Projects: – deep borehole campaign	57 020	39 596
– others	29 112	20 614
Communication	895	1 716
Fees (ENSI, SFOE)	8 743	9 325
Travel expenses	453	802
Project-related external services	**96 223**	**72 053**

C4) Staff costs

Staff costs, including social contributions, increased by 2.0% to CHFk 20 781 compared to the previous year as part of the resource planning approved by the Board of Directors. The higher expenditure is due to increased recruitment, increases in contributions towards overtime, shift work and standby allowances as well as increased contributions to the retirement fund. The deferral for outstanding vacation time and overtime was increased by CHFk 64. The average staffing level in 2020 was 104.6 full-time positions, 9.1 temporary positions and 1.4 apprenticeships (2019: 107.8 full-time positions, 7.8 temporary positions and 1.6 apprenticeships).

C5) Other operational costs

Other operational costs include rents and expenditure on property of CHFk 1 127, expenditure on information technology of CHFk 748 and further operational costs of CHFk 964. These costs are comparable to those of the previous year.

C6) Trade receivables

Compared to the previous year, trade receivables slightly decreased by CHFk 88. As there were no identifiable credit risks as per the end of 2020, no value adjustment was made.

C7) Other current receivables

Other current receivables include cash contributions for securing the centralised billing procedure of the Swiss Federal Customs Administration (CHFk 842) and for various smaller assets (CHFk 23).

C8) Non-invoiced services

Non-invoiced services consist of accrued internal services and third-party services for various projects. Project-specific verification is available.

C9) Accrued income and prepaid expenses

Accrued income and prepaid expenses compose the balance of promised repayments from the deep borehole campaign amounting to CHFk 251, the pre-payments for Suva 2021 (CHFk 183) and the credit of CHFk 21 resulting from excess payments to the Swiss social security insurance (AHV) in 2020.

C10) Tangible fixed assets

	Land and buildings	Office and workshop	Vehicles	Total
	CHFk	CHFk	CHFk	CHFk
Acquisition value per 01.01.2019	**1 825**	**961**	**669**	**3 455**
Additions		118	121	239
Disposals			–31	–31
Acquisition value per 31.12.2019	**1 825**	**1 079**	**759**	**3 663**
Additions		219	86	305
Disposals			–83	–83
Acquisition value per 31.12.2020	**1 825**	**1 298**	**762**	**3 885**
Accumulated depreciations per 01.01.2019	**495**	**888**	**542**	**1 925**
Additions	30	101	72	203
Disposals			–31	–31
Accumulated depreciations per 31.12.2019	**525**	**989**	**583**	**2 097**
Additions	30	120	89	239
Disposals			–83	–83
Accumulated depreciations per 31.12.2020	**555**	**1 109**	**589**	**2 253**
Carrying value per 01.01.2019	**1 330**	**73**	**127**	**1 530**
Carrying value per 31.12.2019	**1 300**	**90**	**176**	**1 566**
Carrying value per 31.12.2020	**1 270**	**189**	**173**	**1 632**

C11) Trade payables

Compared to the previous year, trade payables increased by CHFk 679 to CHFk 7398, mainly due to commitments from the deep borehole campaign.

C12) Advance payments received

Advance payments received are for accrued internal services and third-party services for various projects. Project-specific verification is available. Due to the higher volume of third-party contracts, the advance payments received as per 31st December 2020 rose by CHFk 344 to CHFk 3 849.

C13) Deferred income and accrued expenses

The majority of the deferred income and accrued expenses is formed by the balance of the year-end result (CHFk 9841). Other items (CHFk 10125) primarily comprise deferrals related to outstanding settlements of services that are largely based on previously rendered services within the framework of the deep borehole campaign. Additional deferrals include fees of the SFOE for the 4th quarter of 2020 in the amount of CHFk 1076 and of ENSI in the amount of CHFk 1044. The deferral for the head office amounts to CHFk 1 024 and for outstanding vacation time and overtime, it amounts to CHFk 1 881.

C14) Equity

The Cooperative capital is unchanged with CHFk 140 and is divided into 140 share certificates of CHF 1 000 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:	31.12.2020	31.12.2019
	CHF	CHF
Contribution statement December	257 796	242 573

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 2020.

As of 31st December 2020, there were no guarantee obligations.

Risk report 2020
On 30th June 2020, the Board of Directors approved Nagra's risk report for 2020.

Remuneration disclosure of the Statutory Auditor (in accordance with Art. 961a of the Code of Obligations)
The Statutory Auditor claimed the following remuneration:

	2020	2019
	CHF	CHF
Audit of the annual financial statements	24 000	24 000
Additional audits	3 000	18 000
Total	**27 000**	**42 000**

(excluding expenses and VAT)

Accumulated accounts including adjustments

Note	Total income	Increase 2019 CHF	Excluding interest: adjustment payments 2019 CHF	Status 01.01.2020 CHF	Increase 2020 CHF	Excluding interest: adjustment payments 2020 CHF	Status 31.12.2020 CHF
	Swiss Confederation	2 650 008	–	44 948 273	8 408 970	91 627 759	144 985 002
	Axpo Power AG	20 660 514	–	337 034 948	24 411 233	–21 273 221	340 172 960
	BKW Energie AG	10 550 175	–	160 302 658	11 980 216	–10 914 330	161 368 544
	Kernkraftwerk Gösgen-Däniken AG	25 048 901	–	435 001 224	30 223 655	–26 299 055	438 925 824
	Kernkraftwerk Leibstadt AG	32 840 150	–	519 508 240	38 653 837	–33 141 153	525 020 924
	Contributions to project expenditure	**91 749 748**	**–**	**1 496 795 343**	**113 677 911**	**–**	**1 610 473 254**
	Contributions to administration costs	700 000	–	91 670 000	700 000	–	92 370 000
	Contributions of Cooperative members to Nagra	**92 449 748**	**–**	**1 588 465 343**	**114 377 911**	**–**	**1 702 843 254**
	Contributions GNW	**–**	**–**	**65 265 331**	**–**	**–**	**65 265 331**
E1	**Total contributions**	**92 449 748**	**–**	**1 653 730 674**	**114 377 911**	**–**	**1 768 108 585**

Explanations pages 59-60

Note	Total expenditure	Increase 2019 CHF	Status 01.01.2020 CHF	Increase 2020 CHF	Status 31.12.2020 CHF
	Geoscientific studies	15 181 643	232 558 347	20 767 568	253 325 915
	Nuclear technology and safety	2 129 156	56 552 166	2 473 315	59 025 481
	Radioactive materials	1 337 811	49 969 172	1 411 969	51 381 141
	Facility planning	1 596 972	36 232 847	1 751 034	37 983 881
	Generic (non-site-specific) work	3 452 948	119 824 484	2 492 438	122 316 922
	General programme costs	4 721 386	109 730 740	4 819 183	114 549 923
	Fees and compensation	4 662 594	79 222 310	4 371 327	83 593 637
	L/ILW programme	**33 082 510**	**684 090 066**	**38 086 834**	**722 176 900**
	Geoscientific studies	38 897 370	417 982 377	53 754 651	471 737 028
	Nuclear technology and safety	3 278 818	82 380 042	4 498 524	86 878 566
	Radioactive materials	1 341 149	30 380 601	1 377 314	31 757 915
	Facility planning	2 200 785	31 810 984	2 607 663	34 418 647
	Generic (non-site-specific) work	3 909 419	139 834 283	3 682 386	143 516 669
	General programme costs	4 377 106	94 639 210	5 299 213	99 938 423
	Fees and compensation	4 662 591	80 943 111	4 371 326	85 314 437
	HLW programme	**58 667 238**	**877 970 608**	**75 591 077**	**953 561 685**
E2	**Project expenditure for repository programmes**	**91 749 748**	**1 562 060 674**	**113 677 911**	**1 675 738 585**
	Administration and general project expenditure	**700 000**	**91 670 000**	**700 000**	**92 370 000**
	Total expenditure for L/ILW and HLW programmes, administration and general project expenditure	**92 449 748**	**1 653 730 674**	**114 377 911**	**1 768 108 585**

Explanations pages 59-60

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 114.4 million (CHF 92.4 million in the previous year) correspond to those in the income statement. A contribution of CHF 0.7 million to administration costs is included.

As a result of the decision of the Federal Council on 27th September 2019, a comprehensive compensation payment was initiated in 2020. In total, the Federal Government compensated the insufficient contributions made in the past by paying CHF 137.2 million (excl. VAT) that was divided among the NPP operators. In line with the general meeting held on 30th June 2020, the corresponding invoice and forwarding of the repayment to the NPP operators was managed by Nagra. The interest share of the repayment amounted to CHF 45.6 million. As the members of the Cooperative have stated the wish to depict the compensation payments nominally, the repayment by the Federal Government is stated as CHF 91.6 million.

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

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 annual financial statements for 2020

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 2020.

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 about 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 2020 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

Fabian Stalder
Audit expert

Zürich, 11th March 2021

Appendices

Waste inventories and volumes

Radioactive waste arises mainly from electricity production in the 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 2020
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 2020. 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 2020, figures rounded)	**Volume (m^3)**	**Activity (Bq)**
Nuclear power plants	3 365	$2.2 \cdot 10^{15}$
Zwilag	2 685	$7.0 \cdot 10^{18}$
Federal government's interim storage facility (MIR) (waste from medicine, industry and research)	1 606	$1.5 \cdot 10^{16}$

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 Zwilag 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)** conditioned	packaged	**ATW (m^3)** [2] conditioned	packaged	**HLW/SF (m^3)** 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 Zwilag operational waste	6	22				
SA-ZWI Zwilag decommissioning waste	461	563	24	24		
BA-MIF MIR waste collected from 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 plant/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]	$7.9 \cdot 10^{16}$ Bq		$2.2 \cdot 10^{16}$ Bq		$1.9 \cdot 10^{19}$ 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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