

**nagra** ● we care

**annual report  
2016**

<b>Foreword</b>	
Corina Eichenberger, President of the Board of Directors	2
Thomas Ernst, Chief Executive Officer	3
<b>Highlights of the year</b>	6
<b>Our mandate</b>	9
<b>Work developments</b>	11
Inventory of radioactive materials	13
Sectoral Plan process	14
<b>Scientific and technical background</b>	23
<b>Rock laboratories</b>	29
<b>International Services and Projects</b>	37
International collaboration	38
<b>Public outreach</b>	41
<b>Organisational structure 2016</b>	46
Members of the Cooperative, Board of Directors, Commissions and Statutory Auditor	48
Organigram of the head office 2016	49
<b>Annual financial statements 2016</b>	51
Comments on the annual financial statements for 2016	52
Balance sheet	53
Profit and loss account	54
Cash flow statement	55
Notes to the financial statements	56
Accumulated accounts	61
Notes to the accumulated accounts	63
Report of the Statutory Auditor	64
<b>Appendices</b>	67
Waste inventories and volumes	68
Publications in 2016	70
Glossary / Abbreviations	71

# Foreword



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

Science plays a key role in the disposal of radioactive waste, making an active contribution at the highest level. This is made possible by Nagra's large national and international scientific network and the intensive collaboration in the field of waste disposal. But science alone is not enough. It gives me great pleasure that, in Switzerland, both the scientific and the societal processes are well on track. The most important point of consensus is that the waste disposal issue has to be solved, with safety having the highest priority.

At first glance, 2016 appears to have been a difficult year. Some would even say a year with setbacks. However, I choose to see 2016 differently – as an important and successful year.

Nagra's employees invested their considerable knowledge, tenacity and time in preparing the supplementary documentation required by ENSI. The main issue here is whether the Nördlich Lägern siting region should undergo further investigation in Stage 3 of the siting process. ENSI announced the main outcome of its analysis of the 2x2 siting proposal at a media event in December, recommending that Nördlich Lägern should be carried forward to Stage 3. ENSI found that the arguments put forward by Nagra regarding maximum disposal depth are based on insufficient data, but confirmed its agreement with Nagra on six of the total of seven proposals. It is expected that the Federal Council will follow the recommendation of ENSI in its decision on Stage 2 at the end of 2018. Thanks to Nagra's forward-looking planning strategy, field investigations were initiated in Nördlich Lägern, allowing further delays in the process to be avoided.

My thanks go to the members of the Board of Directors for their helpful and constructive cooperation, as well as to the Executive Board and all Nagra employees for their sense of responsibility, commitment and competence in working towards safe waste disposal.

A handwritten signature in black ink, appearing to read 'C. Eichenberger'.

Corina Eichenberger

### Thomas Ernst, Chief Executive Officer



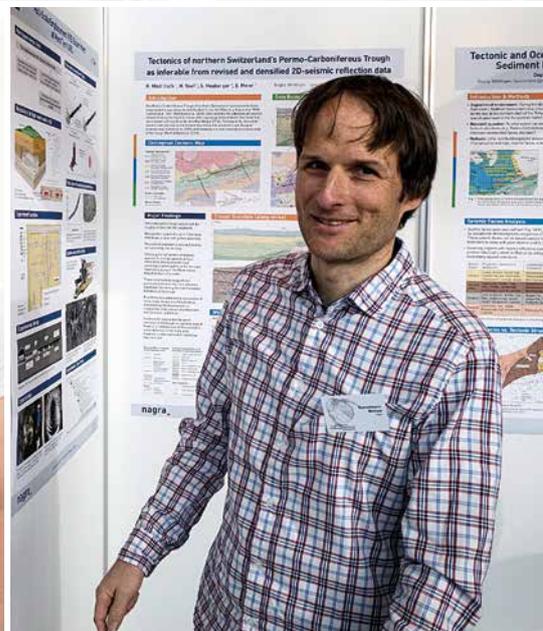
2016 proved to be the most eventful year since I took over as CEO of Nagra ten years ago. The first half of the year focused on preparing the documentation required in response to ENSI's request for additional information for Stage 2 of the Sectoral Plan process. The key issue was the disposal depth indicator, which is relevant for the Nördlich Lägern region. Although a deep geological repository could be constructed safely in Nördlich Lägern, realisation in the Opalinus Clay at great depth is very challenging. Nagra considers this to be a clear disadvantage in terms of safety. ENSI announced the conclusions of its review of Nagra's proposals at the end of the year, finding that Nördlich Lägern should undergo further investigation because the disadvantages put forward by Nagra are not based on sufficiently reliable arguments. ENSI supported Nagra's proposals for the other five siting regions, as well as the decision to focus on the Opalinus Clay.

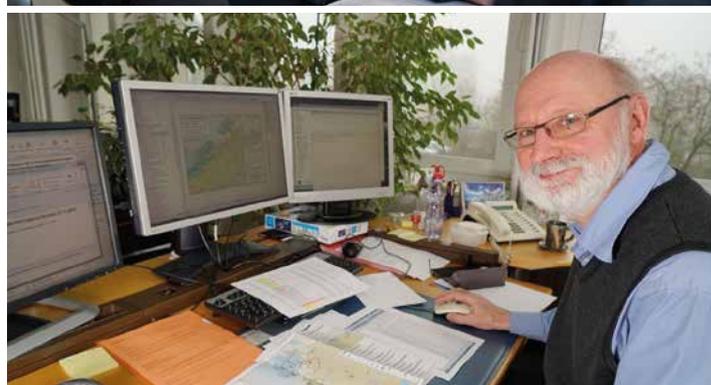
In order to be prepared for every eventuality, Nagra announced in November 2015 that it would begin exploration work in Nördlich Lägern. The 3D seismic measurements in the three regions proposed for further investigation have now been completed successfully and applications submitted for exploratory boreholes. Nagra submitted the 2016 Waste Management Programme at the end of the year. This documents the procedures for planning, constructing and operating a repository up to the time of closure. For the first time this year, it is accompanied by a Research, Development and Demonstration (RD&D) Plan. Nagra also updated the costs of disposal for the 2016 Cost Study. Reports were also produced on the shaft head facilities and the effects of gas production in a repository.

Nagra was reorganised in 2016 with a view to meeting the challenges of the final stage of the Sectoral Plan process and the general licence procedure. The open positions on the extended Executive Board were filled with highly competent members and the age structure was rejuvenated.

All this was made possible by the dedication of our staff and they deserve our recognition and gratitude.

Dr. Thomas Ernst





#### WE ARE NAGRA

110 people work every day on the important task of disposing of Swiss radioactive waste. They come from more than 10 countries; besides Switzerland, these include Germany, Austria, Italy, the Czech Republic, Belgium, Holland, Scotland, Spain, Finland, England, Greece, Japan and Sweden. The youngest employee is 18 and will complete his commercial apprenticeship in 2017. The oldest-serving employee has been with Nagra since June 1982.

# Highlights of the year



**FEBRUARY** The 3D seismic measurements in the Zürich Nordost region are completed at the end of February. These investigations supplement existing data from the measurement campaign conducted in 1997.

**FEBRUARY** Since 29<sup>th</sup> February 2016, a new blog ([www.nagra-blog.ch](http://www.nagra-blog.ch)) offers an insight into Nagra's working world. The employees themselves write the contributions on topics such as field work, research, exhibitions and working with schools and young people.



**28<sup>th</sup> April:** Nagra is certified as a family-friendly organisation.

**APRIL** As part of the organisational development with a view to the third and final stage of the site selection process, three new members take their place on Nagra's Executive Board: Maurus Alig, Coordinator Major Project Sectoral Plan Stage 3 & Licensing, Patrick Senn, Division Head Planning & Construction of Deep Geological Repositories and Tim Vietor, Division Head Safety, Geology & Radio-active Materials.

**APRIL** Nagra is certified by the expert body 'UND' as an employer who balances work and family life. The quality label signifies family-friendly working conditions and gender equality.



**11<sup>th</sup> August:** Nagra submits the additional documentation required by ENSI on the indicator "Depth with respect to engineering feasibility".

**MAY** At the spring meeting of the international EDRAM association in Idaho Falls, USA, Thomas Ernst, CEO of Nagra, is elected as the new president for a period of two years.

**AUGUST** Nagra submits additional documentation to the Swiss Federal Nuclear Safety Inspectorate (ENSI) as requested in September 2015 and specified in more detail in November 2015. In Nagra's view, the siting proposals made in January 2015 can be confirmed: constructing a repository at a depth greater than 600 metres for low- and intermediate-level waste and 700 metres for high-level waste represents a disadvantage in terms of safety. The disposal concept assumed to date has also established itself as preferable to other concepts.



**27<sup>th</sup> September:** Nagra submits 16 applications for exploratory boreholes in the siting regions Jura Ost and Zürich Nordost.



**24<sup>th</sup> October:** 3D seismic measurements start in the Nördlich Lägern region. The area being measured covers 91 square kilometres.



**20<sup>th</sup> December:** For the first time, Nagra submits a Research, Development & Demonstration Plan together with the 2016 Waste Management Programme to the SFOE.

**SEPTEMBER** Nagra submits 16 applications for exploratory boreholes, eight for each of the siting regions Jura Ost and Zürich Nordost. These boreholes require a permit from the Department of the Environment, Transport, Energy and Communications (DETEC), as specified in the Nuclear Energy Act. The main purpose of the boreholes is to explore the geological and hydrogeological properties of the underground rock layers.

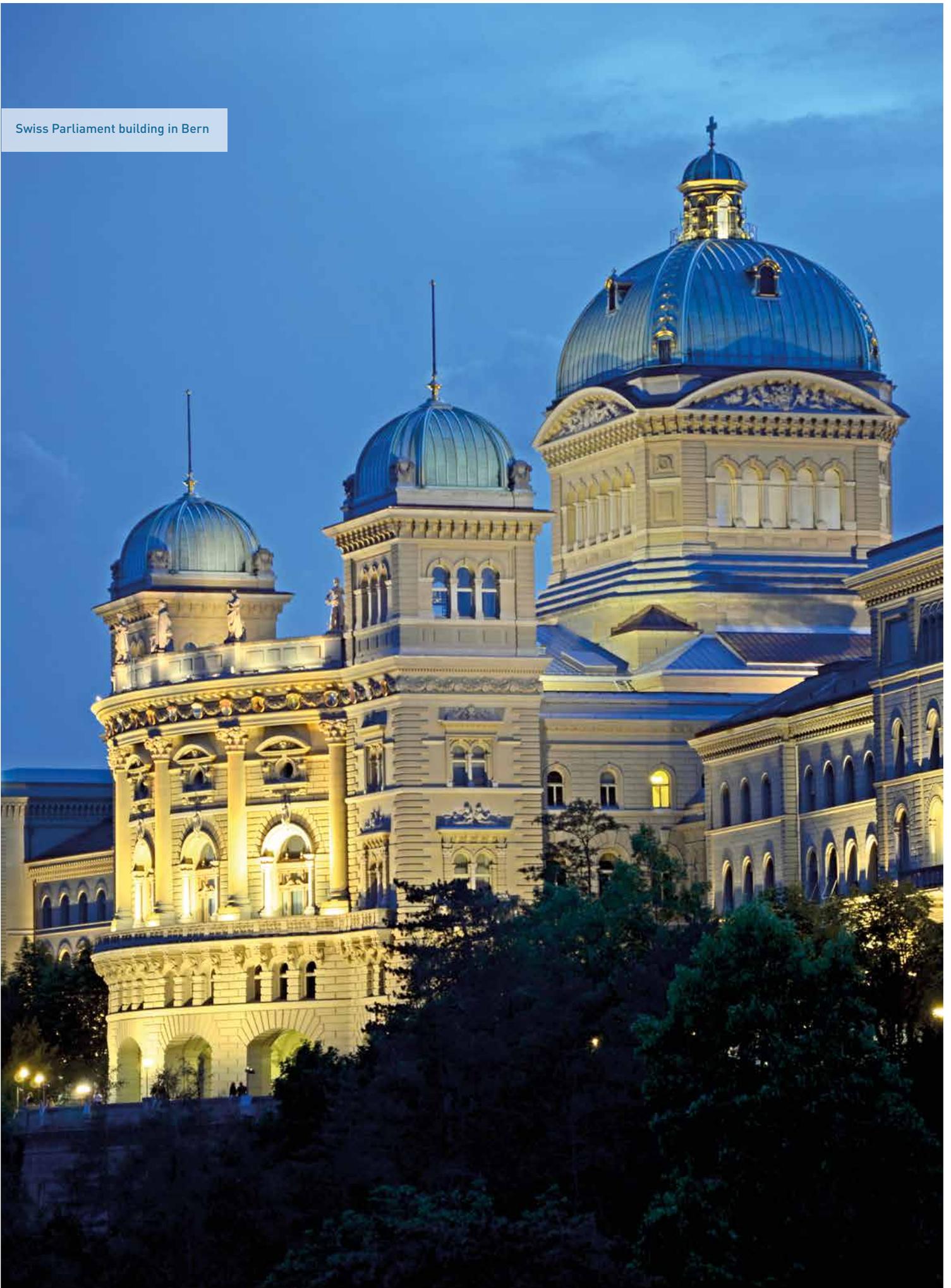
**OCTOBER** After Zürich Nordost and Jura Ost, 3D seismic investigations begin in the Nördlich Lägern siting region from 24<sup>th</sup> October. The measurements will continue until February 2017.

**NOVEMBER** On 15<sup>th</sup> November, Nagra publishes a technical report on the shaft head facilities and auxiliary access facilities of a deep geological repository. Auxiliary accesses and their installations at the surface are described generically in the report.

**DECEMBER** On 14<sup>th</sup> December, at a media conference hosted by the Swiss Federal Office of Energy (SFOE) in Brugg, ENSI recommends that Nördlich Lägern should also be carried forward for further investigation in Stage 3 of the Sectoral Plan process. This is contrary to the proposals made by Nagra in January 2015. At the same time, ENSI approved the other proposals made by Nagra, agreeing that the siting regions Südranden, Jura-Südfuss and Wellenberg, investigated for a low- and intermediate-level waste repository, should be placed in reserve. ENSI also agreed that the focus should be on the Opalinus Clay host rock. The decision of the Federal Council on Stage 2 is expected for the end of 2018.

**DECEMBER** Nagra submits the 2016 Waste Management Programme to the SFOE. The Programme is updated every five years and documents the basic procedures for the planning, construction and operation of a deep geological repository up to the time of its closure. The Programme is also accompanied by a Research, Development and Demonstration (RD&D) Plan.

Swiss Parliament building in Bern



# Our mandate

Deep geological disposal of radioactive waste is a technically and societally challenging task. Nagra approaches its mandate with the necessary respect and a sense of responsibility for cross-generational protection of man and the environment.

According to the nuclear energy legislation, the polluter pays principle applies to the management of radioactive waste. The Cantons are the main shareholders in the electricity utilities that operate the nuclear power plants; this means that not only the power plants, Nagra and the Federal Government but also the Cantons are responsible for waste management.

Radioactive waste arises from the operation and later decommissioning of the nuclear power plants and from a range of applications in the fields of medicine, industry and research (MIR waste).

Nagra was set up in 1972 by the Swiss waste producers and given the mandate of developing and implementing safe, sustainable solutions for the disposal of the waste. The members of the Nagra Cooperative are the nuclear power plant operators, the Zwiilag interim storage facility and the Swiss Confederation (responsible for MIR waste).

Nagra is responsible within the defined legal framework for planning, constructing and operating deep geological repositories. This task of national significance includes selecting suitable sites in line with the Sectoral Plan for Deep Geological Repositories, which is under the lead of the SFOE. Nagra prepares siting proposals that are then reviewed by the responsible authorities and commissions. This is followed by a broad consultation phase before the Federal Council makes a decision. Nagra also submits the licence applications for the planned repositories: one for low- and intermediate-level waste (L/ILW) and one for spent fuel, high-level and long-lived intermediate-level waste (SF/HLW/ILW), or for a combined repository for both categories.

Nagra maintains inventories of radioactive materials and advises the waste producers on conditioning of the waste into a form suitable for dis-

posal. A wide-ranging research and development programme has also been underway since the seventies. In this context, Nagra works closely with the Paul Scherrer Institute (PSI, Villigen) and various universities and technical institutes both in Switzerland and abroad.

## OUR ACTIVITIES

- Working together with the authorities and the siting regions within the framework set by the Sectoral Plan process
- Characterisation and inventorying of radioactive materials as the basis for planning repository projects; checking waste specifications as part of official waste clearance procedures and as a service to the members of the Nagra Cooperative
- Acquisition and evaluation of the field data required for safety analyses and repository projects
- Designing the repository facilities and engineered barrier systems and planning operating procedures
- Ongoing analysis of results and data as part of safety assessment studies and evaluation of the knowledge base with a view to upcoming repository licensing procedures
- Development of databases and refining, verifying and validating the data and models used in safety analysis
- International collaboration with the aim of optimising planning and development activities
- Informing the public
- Providing expert services to third parties



Looking into the central part of the controlled zone at the Grimsel Test Site.

# Work developments

## Legislation and authorities

The Swiss Federal Office of Energy leads and coordinates the Sectoral Plan process. ENSI is the national regulatory body with responsibility for the safety and security of the Swiss nuclear installations. In this capacity, it monitors Nagra's siting investigations for the deep geological repositories and will supervise the later construction and operation of the facilities. The Expert Group on Nuclear Waste Disposal (EGT) was set up by ENSI to provide support to the regulator on engineering and geological aspects of deep geological disposal. The EGT also has responsibility for certain tasks within the framework of the Sectoral Plan process.

The Federal Nuclear Safety Commission (NSC) advises the Federal Council, DETEC and ENSI on questions of nuclear safety. The Nuclear Waste Management Advisory Board was set up by DETEC to advise the Department on the implementation of the repository site selection process within the framework of the Sectoral Plan. It is able to offer an outside perspective thanks to its independent status and its position as a national advisory board.

## Decommissioning and Waste Disposal Funds

The Waste Disposal Fund secures the financing of the disposal of reprocessing waste and of operational waste and spent fuel assemblies following the shutdown of the nuclear power plants. The Decommissioning Fund covers the financing of the decommissioning and dismantling of the nuclear facilities at the end of their operational lifetime and disposal of the resulting waste. The two Funds are fed by contributions by the owners of the nuclear facilities and are supervised by the Federal Government. At the end of 2016, the accumulated capital in the Waste Disposal Fund amounted to around CHF 4.7 billion and in the Decommissioning Fund to around CHF 2.2 billion. More information can be found on the website of the Funds ([www.stenfo.ch](http://www.stenfo.ch)).

## New Cost Study submitted

The cost estimates that form the basis for determining the contributions to the Decommissioning and Waste Disposal Funds were updated in 2016 by

swissnuclear on behalf of the Administrative Commission of the two Funds. The costs for decommissioning of the nuclear installations and disposal of the resulting radioactive waste are now estimated at 22.8 billion Swiss Francs according to the 2016 Cost Study, showing a rise of a total of 10 percent compared to the estimate from 2011. The reasons for this are changes in time plans, modifications to facilities, inflation and new calculation methods. DETEC will set the final annual contributions to be made by the operators of the nuclear facilities to the Funds based on these cost calculations and their review by independent experts.

## LEGAL FRAMEWORK

The legal provisions applying to radioactive waste management are contained in the Nuclear Energy Act and the associated Nuclear Energy Ordinance.

### The following principles apply:

- Radioactive materials should be handled in such a way as to minimise waste production.
- Radioactive waste must be disposed of in a way that ensures the permanent protection of humans and the environment.
- All radioactive waste produced in Switzerland must, as a general rule, be managed and disposed of in Switzerland.
- The duty of disposal lies with the waste producers, in line with the polluter pays principle.
- The management strategy specified for all waste types is monitored deep geological disposal.
- The waste producers are required to prepare a Waste Management Programme, which has to be reviewed and approved by the Federal Government.
- The licensing procedures are focused at the federal level. The general licence for a nuclear installation is subject to an optional national referendum. Participation of the siting Cantons, neighbouring Cantons and neighbouring countries in the process is required by law.
- The Federal Government defines the objectives and requirements applying to the site selection process in a Sectoral Plan.
- The costs of decommissioning and waste disposal are covered by funds into which the operators of the nuclear facilities pay annual contributions; the funds are supervised by the Federal Government.

**The Waste Management Programme – an instrument for long-term planning**

The Nuclear Energy Act and Ordinance require the waste producers to prepare a Waste Management Programme for all types of radioactive waste arising in Switzerland and to update this every five years. The Programme sets out the procedure for realising safe repositories up to the time of their closure and indicates what decisions are to be made and when, what information they are based on and how the information is acquired. These decisions are made as part of the ongoing site selection process according to the Sectoral Plan and in the later licensing procedures. In line with a requirement of the Federal Council, the updated Waste Management Programme (see text-box below) was submitted at the end of 2016 together with the 2016 Cost Study and a Research, Development and Demonstration (RD&D) Plan.

**Sectoral Plan for Deep Geological Repositories**

Article 5 of the Nuclear Energy Ordinance requires the objectives and criteria for the deep geological

disposal of radioactive waste to be specified by the Federal Government in a Sectoral Plan. The Federal Council approved the conceptual part of the Sectoral Plan for Deep Geological Repositories, which regulates the site selection process, on 2<sup>nd</sup> April 2008. The technical feasibility and safety of geological disposal had already been confirmed with the approval by the Federal Council of the high-level waste "Entsorgungsnachweis" feasibility study in June 2006 (the feasibility of safe disposal of low- and intermediate-level waste was recognised in 1988).

The Sectoral Plan process (see figure below) attaches great importance to the requirement for transparent information and participation of the affected parties. The authorities and the public in the siting regions and in neighbouring foreign countries, as well as interested domestic and foreign organisations, may participate in the process, which ends with a decision of the Federal Council and Parliament on the general licences for the repositories. Their decision is then subject to an optional national referendum.

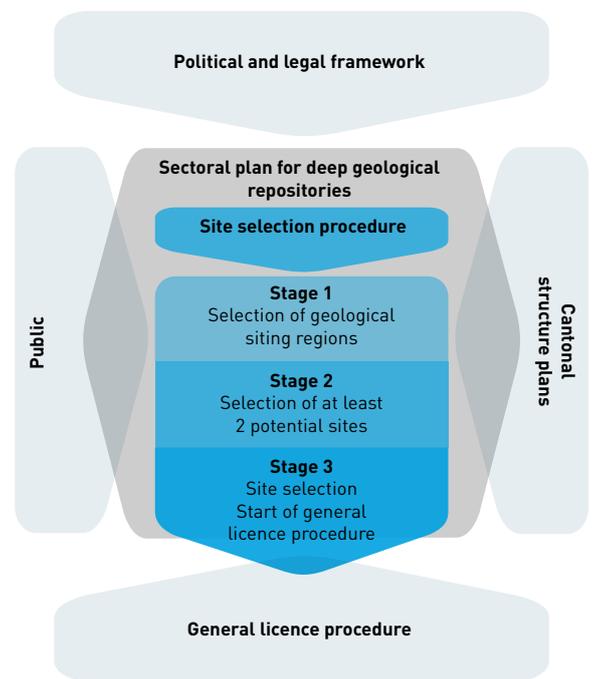
**2016 WASTE MANAGEMENT PROGRAMME SUBMITTED**

The 2016 Waste Management Programme was prepared by Nagra on behalf of the waste producers and updates the first Programme from 2008. It is reviewed by the SFOE, ENSI and the NSC. Following an open consultation process (around the middle of 2018), the Federal Council is expected to decide on the Programme around the beginning of 2019. The Federal Council reports regularly to the Federal Assembly on the status of the Programme.

The 2016 Programme provides the framework for the long-term planning of deep geological repositories. It contains information on the origin, types and volumes of radioactive waste and its allocation to the repositories, as well as the design and layout of the facilities. It also contains an implementation plan and details on financial planning, as well as information on the duration and capacity of interim storage. Nagra also outlines its information strategy in the Programme.

Nagra updated its Research, Development & Demonstration (RD&D) Plan at the same time as preparing the Waste Management Programme and submitted the two reports to the SFOE at the end of 2016 (see text-box on page 23).

**Stages, responsibilities and interactions in the Sectoral Plan for Deep Geological Repositories (figure from the SFOE)**



## Inventory of radioactive materials

The centralised inventory of existing radioactive waste maintained by Nagra was updated to include conditioned waste packages produced in 2016. Modules were also implemented for managing raw waste, in particular assessing it with a view to potential clearance following an optional period of decay storage. The last shipment of reprocessing waste was returned to Switzerland during the year and Nagra was responsible for the quality assurance and consistency check of the accompanying documentation. With the inclusion of these data, the centralised inventory is now complete for reprocessing waste. The “Model Inventory of Radioactive Materials” (MIRAM) was expanded in several areas and modified on the basis of new findings. This related mainly to the properties of waste packaged for disposal and checking waste volumes for the work on the Cost Study and the 2016 Waste Management Programme.

Initial trends are now being recognised from the long-term test on gas production from organic waste that started in Zwiilag in 2015 and preliminary gas formation rates have been derived. For high-level waste, a study has been completed on the criticality safety of spent fuel assemblies in disposal canisters. This included both the handling of the fuel assemblies and their long-term behaviour in a deep geological repository. An experiment programme with international participation was also initiated to investigate the behaviour of fuel assemblies under interim storage and transport conditions. Initial tests have been completed using inactive fuel rods and the test setup for spent fuel rods has been planned.

Development work is being done on future interim storage and final disposal containers for waste arising from the decommissioning of the nuclear power plants; this is being carried out together with the nuclear power plants and Zwiilag and is supported by external companies. A preliminary study has been completed and the results will be used to develop the first prototypes in the coming year. Two further studies looked at the optimisation of decontamination technologies and the treatment of materials and wastes from decommissioning. Work has started on a packaging con-

cept for the reactor pressure vessel, the core internals and the biological shield for the planned decommissioning of the Mühleberg power plant. Tools developed by Nagra for activation calculations will be used for this; these were already used in the 2016 Cost Study.

As part of the procedures for certifying the suitability of wastes for disposal, Nagra has checked waste from the nuclear power plants and PSI for its suitability for later emplacement in a repository. The requirements in ENSI Guideline B05 that underpin the assessment of the waste were observed throughout and led to clearance of the procedures by ENSI.

### CHARACTERISING RADIOACTIVE WASTE – EXCITING WORK!

Ben Volmert, Section Head Inventories & Logistics



“It might be difficult to believe, but my job is really varied and exciting”, says the physicist Ben Volmert, who has been working for Nagra for 14 years. Before this, he carried out radiological calculations for Castor containers and interim storage of waste in Germany. He still deals on a daily basis with lots of numbers, nuclear programs and databases. “In the inventory of radioactive waste, we record existing and predicted future wastes separated according to waste type”, explains Volmert. Before the authorities approve a new waste type, there has to be a so-called ‘certificate of suitability for disposal’. “The sooner we become involved by the power plant operators and PSI in establishing a new waste type, the easier it is for us to determine what exactly is in the waste”, he explains. He also works on projects on the decommissioning of the Mühleberg power plant. For example, a computer model of the entire power plant has to be prepared in order to determine the residual activity in the building structures and machine components. Logistics include the planning and optimisation of future transports of radioactive waste from the power plants and interim storage facilities to the deep geological repository. Ben Volmert also enjoys manning the Nagra exhibition stand, which gives him the opportunity to discuss waste management issues with the public. “I can understand why someone would be afraid of the waste”, he says. This is all the more reason to dispose of the waste safely beneath the earth’s surface where it is protected from potentially adverse influences. “We are working on the best possible solution to this.”

# Sectoral Plan process

## CLEAR RULES FOR SITE SELECTION

The criteria and procedures applying to repository site selection were specified with the approval of the conceptual part of the Sectoral Plan for Deep Geological Repositories by the Federal Council on 2<sup>nd</sup> April 2008. The roles of the different actors in the process were also clearly defined. The siting issue is clarified in three stages, working together with the siting Cantons and communities. Safety has the highest priority throughout the entire process, although spatial planning and socio-economic aspects are also taken into consideration.

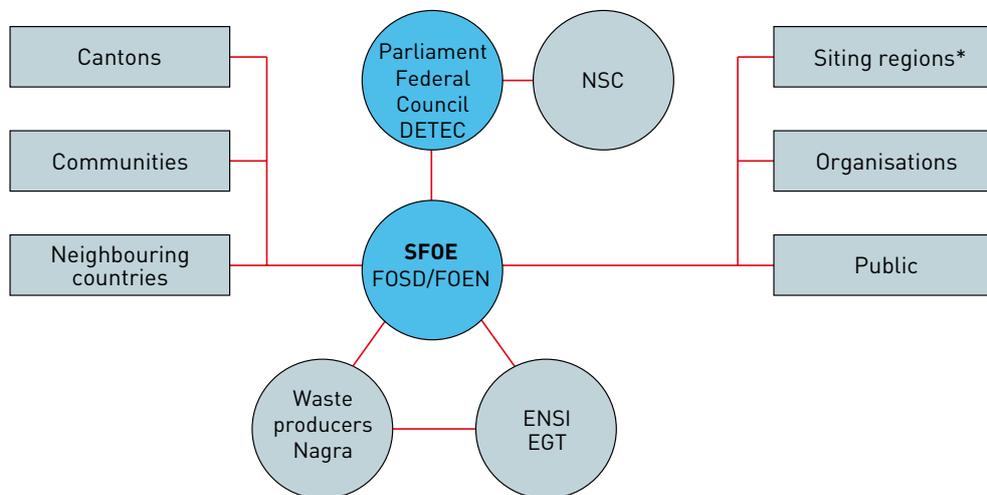
matic approach and the extensive rights of participation granted to a wide range of stakeholders, the Swiss site selection process is considered to be exemplary by other countries with nuclear programmes.

## Federal Government lead – siting proposals by Nagra – independent supervision

The Sectoral Plan process consists of three stages and is led by the SFOE. The process is supported by a large number of advisory bodies and involves the siting Cantons and communities, neighbouring countries, interested organisations and associations, political parties and the public (see figure below). Nagra is responsible for preparing the scientific and technical background for the site selection process, proposing geological siting regions and, finally, sites. Nagra will also submit the general licence applications for the repositories in Stage 3. ENSI reviews Nagra's proposals from the viewpoint of safety and technical feasibility, for which it relies partly on the support of external experts. Each stage includes broad open consultation and participatory phases, after which the responsible authorities and the Federal Council conduct an overall assessment of the situation.

## From “how” to “where”

The fundamental technical question of how to safely dispose of all types of radioactive waste arising in Switzerland has already been answered. The Federal Council approved the feasibility demonstration for low- and intermediate-level waste in 1988 and for high-level waste in 2006. The question of where the repositories can be constructed is being clarified within the framework of the Sectoral Plan for Deep Geological Repositories. Safety always has the highest priority in the search for sites. Because of its transparent, system-



\* The regional conferences represent the siting regions

Actors in the site selection process

### Stage 1 complete

The first stage of the Sectoral Plan process lasted from 2008 to 2011. Starting with the whole of Switzerland, Nagra applied a systematic site selection process based on the safety criteria and the narrowing-down steps prescribed in the conceptual part of the Plan. This resulted in three potential geological siting regions for the HLW repository and six (overlap with three of the HLW regions) for the L/ILW repository. Nagra's proposals were subjected to a rigorous safety-based review by various authorities and technical bodies and a wide stakeholder consultation. The Federal Council decided at the end of 2011 that all six potential siting regions should be carried forward for further investigation and that Stage 2 of the process should be initiated.

### Two tasks for Nagra in Stage 2

One of the tasks to be carried out by Nagra in Stage 2 was to designate at least one siting area for the surface facility of a repository in each of the six siting regions. This work was carried out in close cooperation with the regions. Nagra also had to propose at least two siting regions each for the HLW and L/ILW repositories for more detailed investigation in Stage 3.

### Surface facilities – intensive participation in the siting regions

In contrast with the underground facilities of a repository, the safety of the surface facility depends primarily on the layout and design of the facility itself rather than on the site. The element of flexibility in selecting the siting area for the surface facility is used within the context of regional participation to take the needs and wishes of the region into consideration. At the beginning of 2012, Nagra submitted proposals for siting areas for the surface facility of a potential repository. The regional conferences used these proposals as a basis for discussing the options; some of the regional conferences also made their own proposals. The siting Cantons were also involved in the discussions. Based on a catalogue of criteria agreed together with the responsible cantonal authorities, Nagra identified further potential siting areas and the regional conferences then

decided on a case-by-case basis whether further proposals should be prepared and discussed for these siting areas.

All the regional conferences have responded to the proposals for the siting areas and, based on these responses, Nagra designated the areas to be followed up and documented these in planning studies between September 2013 and May 2014. They form part of Nagra's proposals in Stage 2. With a view to the general licence application in Stage 3, they provide input for the socio-economic-ecological impact studies and for the preliminary investigations for the Environmental Impact Assessment. The latter formed part of the documentation submitted in Stage 2.

#### "I ENJOY MY COORDINATION ROLE"

Hannes Hänggi, Project Manager Stage 3, Sectoral Plan process



"At the beginning I always carried a list of abbreviations for projects and technical terms with me", recalls Hannes Hänggi, who has worked for Nagra since last July. "And the list was put to good use in the first weeks", he adds with a smile. The geologist and former journalist Hänggi is responsible for planning the milestones in the major project Sectoral Plan for Deep Geological Repositories, Stage 3 – a highly complex and detailed task. The most important work steps are divided into key projects with deadlines and these are documented in comprehensive plans. "Of course, I also do the controlling",

he adds. Project management is one of his main interests. "Coordination is my strong point – I have noticed this before", says Hannes Hänggi. And it drives him to look together with his colleagues for ways to make sure that the work not only complies with the requirements of the Federal Government but is also carried out as efficiently as possible.

Before Hannes Hänggi joined Nagra last year, he was employed by ENSI in several different roles. He worked initially in a management support position, with responsibility for answering questions from the public and parliamentarians and for managing ENSI's website. He later became internal project manager for the decommissioning of nuclear installations and helped to build up the Decommissioning Section, later taking over as deputy head.

At Nagra, he coordinates the collaboration with the authorities such as ENSI and the Swiss Federal Office of Energy. Writing reports is also part of his job. His work requires a broad understanding of the scientific-technical topics that fall under Nagra's area of responsibility. "It was helpful that I already knew something about the topic of waste disposal", explains Hänggi. Preparing reports for Nagra is detailed work, often more detailed than actually required by the regulator. "If we can take the opportunity to simplify things here and there, this allows us to optimise processes", he explains.

### **Proposals for Stage 3**

Deciding which geological siting regions are to be proposed for Stage 3 is a scientific/technical issue. The long-term safety of a repository will be determined by the geology of the selected site. The safety-based comparison of the potential siting regions is complemented by an engineering risk analysis of the underground access structures of the repository.

### **Detailed investigations for the safety-based comparison in Stage 2**

With a view to carrying out the safety-based comparison, Nagra already began in Stage 1 to improve its understanding of the properties of the host rocks and the geological situation in the siting regions. ENSI reviewed the proposed investigation programme and found it appropriate, with some additions, for achieving the required level of knowledge. At the wish of the siting Cantons and the NSC, Nagra also decided to carry out 2D seismic measurements in the regions Südranden, Nördlich Lägern, Jura Ost and Jura-Südfuss already in 2011/12.

Eleven technical meetings were held under the lead of ENSI. During these meetings, the Expert Group on Nuclear Waste Disposal, the Nuclear Safety Commission, the Cantonal Working Group on Safety (AG SiKa), the Cantonal Expert Group on Safety (KES), the SFOE, a representative of the German Federal Ministry for the Environment, Nature Conservation, Building and Reactor Safety (BMUB), Nagra and various technical experts evaluated how the required knowledge had advanced. ENSI confirmed in August 2014 that the geological knowledge base was sufficient for Nagra to proceed with the safety-based comparison.

### **Method for comparing the siting regions is defined in advance**

ENSI defines the method to be used by Nagra for the comparison of siting regions. This was specified in 2012, with input from the NSC and cantonal experts, and documented in an ENSI memorandum in January 2013. According to the method, a siting region is placed in reserve only if it shows clear disadvantages in terms of safety compared

with the other regions. If this is not the case, the region will undergo further investigation in Stage 3. ENSI has also defined the requirements for the engineering risk analyses and for the supplementary safety analyses for the underground access structures.

### **Safety-based comparison and Nagra's siting proposals**

All six geological siting regions meet the strict safety requirements specified by the Federal Government and are thus suitable for constructing deep geological repositories. However, a detailed comparison shows clear differences with respect to long-term safety. In Nagra's view, compared to Zürich Nordost and Jura Ost the other regions have clear disadvantages in terms of safety, even if they are suitable in principle from a safety perspective. Nagra therefore proposed to carry the siting regions Zürich Nordost and Jura Ost forward for further investigation in Stage 3 and to place the siting regions Südranden, Nördlich Lägern, Jura-Südfuss and Wellenberg in reserve. Both regions are suitable for a L/ILW or HLW repository and also for a combined repository. The supporting documentation was submitted to the SFOE on 30<sup>th</sup> December 2014.

### **Detailed review of the siting proposals**

ENSI, the NSC and other federal offices are currently reviewing Nagra's proposals. ENSI has called on external experts to provide support, in particular the Expert Group on Nuclear Waste Disposal. The proposals were also submitted to the Cantons represented on the Cantonal Commission and they have been examining them in some detail. The Cantonal Working Group on Safety is supported by a cantonal-level group with external experts.

In September 2015, the SFOE announced that Nagra would be required to submit additional technical documentation on the indicator 'Depth with a view to engineering feasibility'; this is particularly relevant for the Nördlich Lägern siting region. ENSI further concretised its requirements in November 2015. Nagra then prepared a main report and several reference reports and these were sub-

mitted to the SFOE in August 2016. Besides geo-mechanical and engineering aspects of constructing the emplacement drifts and caverns in the Opalinus Clay at different depths, alternative disposal and barrier concepts were also analysed, the demarcation of the disposal perimeters was reviewed and additional dose calculations were carried out.

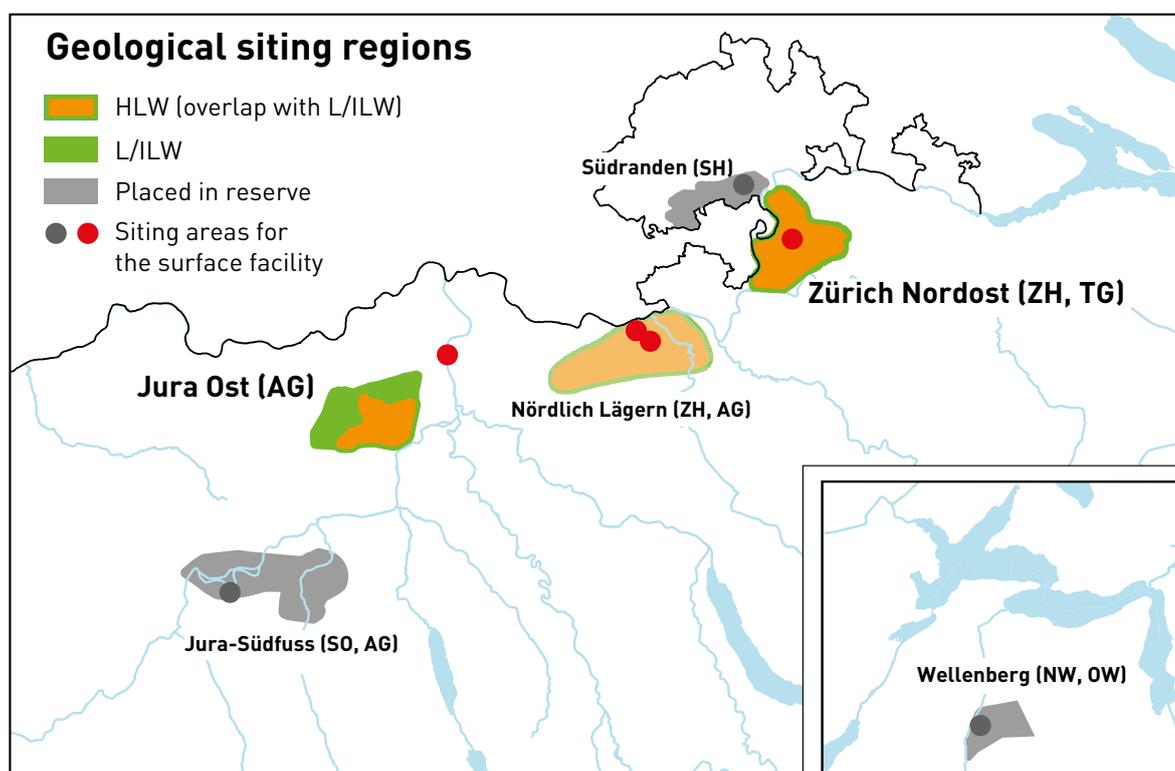
Nagra still stands by its original conclusion: a repository can be constructed safely in Nördlich Lägern, but this is very challenging at greater depth in the Opalinus Clay. For Nagra, this represents a disadvantage in terms of safety.

#### Conclusions of the review already published

ENSI presented the results of its review of Nagra's siting proposals in mid-December 2016. ENSI agrees that the siting regions Südranden, Jura-

Südfuss and Wellenberg proposed for a low- and intermediate-level waste repository should be placed in reserve. It also agreed that the focus should be on the Opalinus Clay as the host rock. Zürich Nordost and Jura Ost should undergo further investigation in Stage 3; both are suitable for a HLW and a L/ILW repository or a combined repository. However, ENSI is of the opinion that the Nördlich Lägern siting region should also be carried forward to Stage 3 as the reasons for placing it in reserve are not sufficiently reliable. The details of ENSI's decision and the final review are expected for spring 2017.

The Cantonal Working Group on Safety and the Cantonal Expert Group on Safety (AG SiKa/KES) came to a similar conclusion in a technical report published in January 2016, agreeing that Nördlich Lägern should not be placed in reserve.



Based on an extensive investigation programme and the results of the safety-based comparison, Nagra proposed the siting regions Zürich Nordost and Jura Ost for further investigation in Stage 3 (HLW = high-level waste, L/ILW = low- and intermediate-level waste). At a media event hosted by the SFOE in December 2016, ENSI recommended investigating the Nördlich Lägern region further in Stage 3 of the Sectoral Plan process. The Federal Council decision is expected at the end of 2018.

### **The regional conferences evaluate transparency**

The regional conferences also responded to Nagra's siting proposals. They assess the transparency of the proposals and the progress of the site selection process to date. With the completion of the report of the Zürich Nordost regional conference in March 2016, responses are now available from all the siting regions on the Stage 2 proposals. The regional conferences once again considered the work on Stage 2 critically and with great commitment.

### **Broad consultation of all interested parties before the Federal Council decision on Stage 2**

The SFOE will make an overall evaluation of the proposals based on the reviews by the authorities and the opinions of the Cantonal Commission and the regional conferences. In 2017, all the reports, expert opinions and evaluations will undergo a three-month public consultation process. With all relevant facts to hand, the Federal Council is expected to reach a decision on Nagra's proposals in 2018 and will then decide on the conclusion of Stage 2 of the process.

### **Preparing for the third and final stage**

A consolidated plan now exists for the final stage of the Sectoral Plan process. Nagra's task is to carry out geological investigations in the siting regions remaining in the process, followed by a further safety-based comparison. Based on this, the selection of the sites for which general licence applications will be prepared will be made by 2022. The projects will be further concretised together with the regions and the Cantons before the licence applications are submitted around 2024.

Nagra has already started a phase of geological investigations and field work in the siting regions in preparation for Stage 3.

### **3D seismic measurements complete**

The first step in the field investigations was to perform 3D seismic measurements. For Jura Ost and Zürich Nordost these lasted from October 2015 to February 2016. The measurements in Zürich Nordost complemented an existing 3D campaign from

## **REGIONAL CONFERENCES**

The regional conferences represent the interests of the siting regions in the participation process. They are made up of between 85 and 110 members, including representatives of local communities, regional organisations (e.g. associations or political parties) and individual members of the population.

Each regional conference has set up technical working groups that are responsible for considering specific topics in more depth and providing opinions on these. All the regions have working groups on the surface facility, the socio-economic-ecological study and repository safety. The SFOE guides and supports the work of the conferences.

### **Current information on the regional conferences (websites in German):**

Südranden\*:  
[www.plattform-suedranden.ch](http://www.plattform-suedranden.ch)

Zürich Nordost:  
[www.zuerichnordost.ch](http://www.zuerichnordost.ch)

Nördlich Lägern:  
[www.regionalkonferenz-laegern.ch](http://www.regionalkonferenz-laegern.ch)

Jura Ost:  
[www.jura-ost.ch](http://www.jura-ost.ch)

Jura-Südfuss:  
[www.jura-suedfuss.ch](http://www.jura-suedfuss.ch)

Wellenberg:  
[www.plattform-wellenberg.ch](http://www.plattform-wellenberg.ch)

\* Work suspended in autumn 2015

1997. Measurements in Nördlich Lägern began in October 2016 and were completed in February 2017. Around 98% of the affected landowners and land managers who were contacted personally agreed to allow access to their land. Irrespective of their personal views on deep geological disposal, in this way they indicated their understanding that the work was necessary in the interests of safety. A comprehensive database was thus acquired for all three regions and data processing, analysis and interpretation have already begun.

### Applications for exploratory boreholes

The planned exploratory boreholes (deep boreholes) represent a further important investigation tool in the three regions. These boreholes require a permit from DETEC. Nagra conducted discussions with the Cantons, local communities and landowners with a view deciding on the locations of the drillsites; these have to be in line with the geological and spatial/environmental planning boundary conditions. Nagra submitted eight applications to the SFOE for each of the siting regions Jura Ost and Zürich Nordost at the end of September. The applications for Nördlich Lägern are expected for summer 2017. Work on the boreholes will begin after the decision of the Federal Council on Stage 2.

### Quaternary investigations and other work

The evolution of the land surface over the last two million years is investigated using layers of unconsolidated sediments. The aim is to be able to predict future long-term evolution, particularly of surface erosion, over several 100 000 years. Valleys that were overdeepened by glaciers and then refilled are investigated using 2D seismic cross-profiles and boreholes. These so-called Quaternary boreholes extend only a few metres into the consolidated rock and are comparable with boreholes drilled for geothermal heat exchangers. Further geological investigations and studies will supplement the datasets used for site selection and the general licence applications.

### Concretising the projects – discussion of auxiliary access facilities

Various facilities at the surface and underground are required for the operation of a deep geological repository. Additional accesses are required besides the surface facility and the main access for the transport of the radioactive waste from the surface to the underground facilities. In the case of shafts, these are the so-called shaft head facilities; in the case of tunnels (ramps) they are termed portals. In November 2016, Nagra published a technical report providing a generic description of these auxiliary accesses and their infrastructure at the surface.

In Stage 3 of the process, potential locations for the auxiliary access facilities will be identified working together with the regions and Cantons. The purpose of the technical report is to set the background for supporting the regions and Cantons in their decision on the location and layout of these facilities.

#### "I AM A GENERALIST WHO ENJOYS WORKING IN DIFFERENT TECHNICAL AREAS"

Marc Croket, Project Manager Facilities & Operation



The chemical engineer Marc Croket is involved, amongst other things, in the design and layout of facilities. He also specifies the systems and operating procedures in a future radioactive waste repository. Together with his co-authors, Marc Croket prepared a report in 2016 on the shaft head facilities of a deep geological repository. The report provides a detailed description of all the surface facilities for auxiliary accesses to the repository – so-called auxiliary access facilities – and explains the operating procedures. Visualisations

are also available that give the reader a first impression of how these facilities will look and what impacts they could have.

For Marc Croket, writing the report was an exciting challenge: "The topics involved are multifaceted and multidisciplinary, ranging from construction engineering to safety considerations. I am more of a generalist who enjoys working with different technical experts and then bringing their input together into a coherent project."

And the next step? The auxiliary access facilities will be defined in more detail using a stepwise approach. In the coming years, it is planned to identify the potential locations for these facilities. "I believe it is important to think carefully about how the facilities can be integrated into the landscape in a way that is acceptable and to discuss this with all parties involved. After all, the structures will be there for some time", says Marc Croket. "Unfortunately it is not clear in the case of a repository whether I will ever see these structures. However, good things are worth waiting for."

A brochure on the shaft head facilities of a deep geological repository was also produced at the same time as the technical report.

**The final step: expected decision via the ballot box**

Based on the results of the investigations in Stage 3, Nagra will select the final repository sites (one each for a HLW and a L/ILW repository or a combined repository) and prepare the associated general licence applications. The applications are reviewed by the safety authorities and the Federal Council and Parliament then decide on the applications. The decision by Parliament is subject to an optional national referendum. If such a referendum is called for, the final say in the Sectoral Plan process would thus lie with the Swiss voters.

An information event on the seismic measurements in the Nördlich Lägern region was held in Weiach in November 2016.



#### WHERE ARE WE NOW?

- Six geological siting regions were identified in Stage 1, three for the HLW and L/ILW repositories and a further three for the L/ILW repository
- Siting areas for the surface facility were designated in Stage 2, working together with the regions
- All six siting regions are suitable in terms of safety, but a detailed comparison shows clear differences
- The siting regions Zürich Nordost and Jura Ost have been proposed by Nagra for further investigation in Stage 3
- The proposals are being reviewed by the authorities
- ENSI announced the overall result of its review in December 2016: Nördlich Lägern should also remain in the process and undergo further investigation in Stage 3
- The Federal Council will make its decision on Stage 2 around the end of 2018





Where land was inaccessible for the vibrator vehicles, 3D seismic measurements were carried out using shot seismics. The photo shows a mobile drilling machine for excavating the shotholes required for blasting.

# Scientific and technical background

The aim of the research and development work in 2016 was to expand the existing knowledge base for evaluating the safety of the deep geological repositories. The R&D activities also contributed to optimising the concepts for the different facilities. Nagra's medium-term objective is to lay the groundwork for the general licence applications in Stage 3 of the Sectoral Plan process. The nature and scope of the work to be carried out are determined on the one hand by the requirements placed by Nagra on this technical basis. They are also based on the results of a review of the current status of science and technology and the planned work derived from this as documented in the updated RD&D report published by Nagra in December 2016 (see text-box below right).

## Geological field investigations

The field work for Stage 3, particularly the 3D seismic measurements, continued according to plan. The seismic measurements that began in October 2015 over an area of around 90 square kilometres in the Jura Ost siting region were completed in January 2016. Measurements were carried out over an area of around 20 square kilometres in the Zürich Nordost region up to the end of February 2016 to supplement existing data.

3D seismic measurements began in Nördlich Lägern in October 2016. The area covered in this case was around 90 square kilometres. Once all the measurements have been analysed, an important knowledge base for evaluating the structure and composition of the geological barrier will be available for all the potential regions in Stage 3. Exploratory boreholes are required for calibrating the seismic measurements.

The boreholes planned in the siting regions require permits from the authorities as specified in the Nuclear Energy Act. Working together with the Cantons, local communities and landowners, suitable locations for the boreholes were identified in the regions Jura Ost and Zürich Nordost and the required applications were prepared. Eight appli-

cations were submitted to the federal authorities for each of these regions in September 2016. The applications for Nördlich Lägern are currently being prepared and will be submitted during the course of 2017.

Other field work is being carried out to investigate near-surface unconsolidated sediments that provide information on the evolution of the landscape in Northern Switzerland. A 2D seismic campaign began in autumn to investigate the structure and distribution of these sediments in more detail. Based on this, applications for Quaternary boreholes will be prepared and submitted in 2017.

## Analyses, modelling and syntheses

As part of the review of Nagra's siting proposals for regions to undergo further investigation in Stage 3, ENSI reached the conclusion that the documentation submitted by Nagra on maximum repository depth is not sufficiently reliable to indicate a significant disadvantage in the case of Nördlich Lägern. This led to a call for further information by ENSI, published in November 2015. Simplified release and dose calculations were carried out as the basis for preparing the required

### RESEARCH AND DEVELOPMENT PROGRAMME (RD&D PLAN) SUBMITTED TO THE SFOE

The R&D Programme forms the basis for planning the ongoing optimisation of the existing repository concepts, with remaining uncertainties being reduced and scientific advances being considered. The planned research activities cover a wide spectrum of topics: from gas transport and consumption in a repository through the behaviour of the engineered barriers to monitoring of a repository. Nagra will also carry out further geological investigations to characterise the underground environment in the siting regions and refine the knowledge of safety-relevant processes in the host rock. Long-term geological evolution, including erosion and climate developments, will also be investigated further.

reports; these assumed erosion of parts of the repository. This was coupled with the unlikely extreme scenario of glacial overdeepening of a valley down to the disposal depth of the HLW repository, which allows the significance of glacial overdeepening to be put in perspective. It was assumed for the calculations that the overdeepened valley will reach part of the repository and radioactive material will be transported from the repository to the surface and deposited downstream of the valley. The resulting doses depend on the material flows associated with erosion and the type of agriculture in the deposition zone. The calculations show that even the doses for this

extremely unlikely scenario lie within the range of natural radiation or significantly below this and that they will decrease only slightly in the time period between 100,000 and one million years under the same conditions. Longer protection from erosion is thus of little significance in terms of reducing dose.

### **Geochemical retention processes and transport mechanisms**

Industrially produced cements foreseen as a backfill material in the repository for low- and intermediate-level waste or long-lived intermediate-level waste have certain amounts of aluminium compounds in their additives. Aluminium is also contained in the waste itself. It is important for the safety analysis to understand the influence of aluminium on the long-term evolution of the cement backfill as this makes an important contribution to radionuclide retention (cement barrier). Earlier studies on the composition and structure of an important component of the cement (so-called calcium-aluminium-silicate-hydrate (CASH) phases) were expanded by modelling the interactions on a molecular level. The results show that the incorporation of aluminium is favourable for the cross-linking of the silicate structure, which agrees with the results of experimental nuclear magnetic resonance measurements. This cross-linking increases the long-term stability of the CASH phases and thus of the cement barrier.

### **Investigations on gas pressure build-up and gas transport**

A synthesis report has been prepared on the most recent understanding of the production, transport and consumption of gaseous substances in a closed repository. The accompanying reference reports address topics such as the waste inventory and potential waste treatment methods, as well as other aspects of gas production, consumption and transport.

For the synthesis report and reference reports, the influence of various processes associated with gas on the safety of a HLW and L/ILW repository in Opalinus Clay was evaluated using models and safety criteria relating to intact engineered and

#### **“I AM REALLY HAPPY TO BE WORKING ON SUCH AN IMPORTANT DRILLING PROJECT”**

Michael Gysi, Project Manager Drillsite Geology



“I enjoy the mix between planning in the office and field work”, says geologist Michael Gysi. For Nagra’s upcoming exploratory boreholes, or “deep boreholes” as they are termed in the technical jargon, he will have responsibility for collecting and characterising drilling samples. Planning for this work is already well underway. “Practical hands-on work on drillsites is always a welcome change”, he comments. He is currently in charge of the ongoing shallow

borehole campaign and measurements in Nördlich Lägern. The data from these investigations will be used to calibrate the 3D seismic measurements.

After studying as an exploration geologist, his work originally took him abroad. He worked on geological mapping and ore exploration in the field in Africa and then for several years as a geo-modeller and geologist in the oil industry, using geological data to construct 3D models of the underground. Similar models will also be developed for Nagra at a later stage. “We will use measured data to reconstruct deposition processes in the past and will then implement these in models. For example: this is a river channel here or the sand was deposited from this direction”. The drillcores from the exploratory boreholes are very important for these modelling exercises because the rock can be characterised both visually and in the laboratory and it is not necessary to rely only on geophysical measurements.

In the future borehole programme, which is planned from 2019, Michael Gysi will be responsible for coordinating and monitoring the processes surrounding the drillcores. “Nowadays, online monitoring is possible to a large extent but this does not mean I will just be sitting in my office”, he says. He enjoys being outside on a drillsite too much, explains Gysi, who can now put his knowledge in the area of resource exploration to practical use. “As a student, my dream was to be involved in the construction of the Gotthard tunnel. That I now have the possibility to work on such an important drilling project is really amazing”, he adds.

natural barriers. The relevant uncertainties and design variants were considered in specific calculation cases. Examples of such uncertainties and variants are potential waste treatment options (e.g. melting), uncertainties regarding heat- and gas-producing processes and their interactions, possibilities for designing closure and sealing structures and uncertainties relating to the gas and heat transport properties of the individual repository components and rock. The calculation results give the expected value ranges for safety-relevant parameters such as gas pressure, gas saturation and temperature and the potential impacts of measures for reducing gas production. There were also indications of what research work should be undertaken to further reduce existing uncertainties.

The main conclusion of the report is that, even in a very unfavourable case, gas production does not present a hazard to the safety functions of the host rock and the engineered barriers in either a HLW or L/ILW repository. For all the cases investigated, there is a sufficient margin between the calculated results and the derived safety criteria. There are also several possibilities for further reducing gas production.

#### **Knowledge relevant for the L/ILW repository**

Gas production in the L/ILW repository is dominated by hydrogen from the corrosion of carbon steel. Parameters that significantly influence gas production in the repository are the amounts of steel components and their geometry, the corrosion mechanisms and rates and the geochemical and hydraulic conditions during the relevant period for safety assessment. Alternative packaging technologies and melting of metals could considerably reduce the production of gas. The build-up of a gas overpressure and resulting displacement of porewater can be mitigated to an acceptable level by suitably designed underground and access structures.

#### **Knowledge relevant for the HLW repository**

Gas production in the HLW repository is also mainly from the corrosion of metals. The currently planned disposal canisters are made of carbon

steel and will be responsible for around 80 % of the gas produced. If necessary, this could be reduced significantly by using alternative canister materials that produce very little or no gas. A further reduction could be achieved by alternative emplacement and backfilling technologies. Besides gas generation, the thermal expansion of porewater due to the heat produced by the high-level waste could also cause a significant build-up of pressure in the repository. The calculated maximum pressures are comparable with, or even higher than, those caused by gas production. This underlines the need for a sufficiently long period of interim storage, optimised canister loading and an optimised layout of the disposal rooms and disposal canisters. The gas-induced and heat-induced pressure build-ups do not overlap in time.

#### **Alternative canister designs and materials**

The concept of a copper-coated SF/HLW canister was further developed together with Nagra's Canadian sister organisation NWMO, with more prototypes being produced on a 1:1 scale. The so-called 'cold spray' method was used in the vicinity of the welding seam and electrolytic deposition of the copper layer for the rest of the canister surface. Further optimisation is planned. The design for a Nagra-specific copper-coated SF/HLW canister was also refined. A number of alternative design concepts were developed, including a new variant that offers space for twelve instead of nine spent fuel assemblies from boiling water reactors. The possibility of using cast iron as a canister material to ensure structural stability is also being investigated. A study being carried out together with The Welding Institute of the UK is evaluating various welding and closure methods for a cast iron canister with a steel lid that are compatible with the copper coating methods.

## A YEAR OF INTENSIVE FIELD WORK

The 3D seismic measurements in Zürich Nordost were completed in February and measurements in Nördlich Lägern began at the end of October. 3D seismics provide a three-dimensional image of the underground geology to a depth of several kilometres. 2D seismic measurements also began in Zürich Nordost to investigate unconsolidated sediments from the Quaternary. This provides information on past erosion processes and tectonic activity. Nagra also drilled 17 shallow boreholes and carried out measurements in the siting regions, with the results being used for near-surface calibration of the seismic measurements.







Scientists from around the world carry out research at the Grimsel Test Site.

# Rock laboratories

## Grimsel Test Site (GTS)

Nagra has been operating the Grimsel Test Site (GTS) since the mid-eighties and more than 20 partner organisations from around the world are currently involved in the projects. The laboratory is located at a depth of 450 metres in the crystal-line formations of the Aar Massif in the Bernese Alps. Besides the different experiments aimed at testing and further developing concepts for safe disposal of radioactive waste in deep geological repositories, the GTS is now recognised worldwide as an important research platform in the general field of geosciences.

### Ideal boundary conditions

The favourable geological conditions, enormous wealth of experience and excellent infrastructure offer ideal working conditions for researchers from a wide range of disciplines. This is reflected in the interest shown by national and international research institutes who are involved in partner projects (e.g. University of Bern, LASMO project) or are performing their own projects (e.g. ETH Zürich, ISC project). Summer schools are also organised at the GTS for various universities (e.g. University of Birmingham).

The GTS partners come together once a year in the Grimsel region for the International Steering Committee Meeting (ISCO). They discuss current research results and financial aspects and decide on the future strategic direction of the rock laboratory.

### Close connections in the local area

The Grimsel Test Site is well established in the local communities of Guttannen, Innertkirchen and Meiringen and continues to work closely with local companies. In September, members of the local authorities from Meiringen visited the rock laboratory and the facility continued to attract numerous visitors and journalists from around the world. Information exchanges were held as part of the highly successful partnership with the local hydropower company Kraftwerke Oberhasli (KWO), from which both sides benefited during the year. There is excellent collaboration with the

operating personnel of the power plants Grimsel I and II, the KWO visitors' service and the Grimsel hotels.

### HOSPITALITY MEETS MANUAL SKILLS

Ann-Sofi & René Dorrer, Operational Services, Grimsel Test Site



"Working in an international environment is really interesting", says Ann-Sofi Dorrer, who has been responsible since 2010 for ensuring that researchers and workers at the Grimsel Test Site have optimum working conditions. She maintains the premises and looks after guests and finds it fascinating when visitors come from Japan, Spain or Korea. She also looks after visitors during guided tours and picks them up from the parking area; she organises the catering and makes sure that the tours run according to schedule.

"My work is very varied", says the native Swede, who has lived in the Grimsel area for many years. "And my workplace is really unusual." The Grimsel Test Site is located at an altitude of 1738 metres above sea-level. There is no daylight in the tunnels or rooms. Ann-Sofi Dorrer has no problem with this. Her commute can be different however. "In the winter months the road conditions at Grimsel can be very difficult due to heavy snowfall and avalanche risk", she explains.

Her husband René Dorrer has been responsible since 2015 for the reliable operation and maintenance of the underground laboratory facilities. He coordinates the different work activities such as boreholes and makes sure that everything runs properly. "I also ensure that the safety regulations are observed", he adds. Before René Dorrer joined the Grimsel team, he worked as an assembly manager for the Oberhasli hydropower company. "One of my jobs was to work together with a group of apprentices to install a throttle valve at a reservoir", he explains. The tunnels belonging to the Oberhasli hydropower company are directly adjacent to the Grimsel Test Site. "My workplace was already familiar to me, not least because my wife always took me along to the open-days", he says smiling.

René Dorrer enjoys working on the different experiments, even if it is hectic at times or his working day is very long. "Things do not always run according to plan", he explains. Sometimes small modifications are necessary. Then it is important to act quickly in order to avoid delays. "We are lucky to have a small workshop in the laboratory which is well equipped with tools and different materials", he adds. He has a clear opinion on radioactive waste disposal. "The waste is presently being stored at the surface and this is not a long-term solution." In the years before the waste is disposed of in a repository, scientific knowledge will continue to be refined. His wife Ann-Sofi adds: "I find it particularly important for future generations that the waste should be disposed of safely on the long term."

## MAIN PROJECTS AT THE GRIMSEL TEST SITE

### CFM (Colloid Formation and Migration) Fundamental aspects of radionuclide migration in crystalline rock

Formation and transport of colloids and their influence on radionuclide mobility

### EBS Lab (Engineered Barrier Laboratory)

Small- to medium-scale experiment with the components of the engineered barriers and measurement of parameters

### FEBeXe/DP (Full-scale HLW Engineered Barriers Experiment Extension/Dismantling Project)

1:1 demonstration of the emplacement concept for high-level waste

### FORGE<sup>1</sup> (Fate of Repository Gases)

Experiments on gas migration in engineered barriers (bentonite/sand)

### GAST (Gas Permeable Seal Test)

Gas sealing experiment: controlled gas transport through the engineered barriers (gas-permeable tunnel seals for the L/ILW repository under realistic conditions and on a realistic scale)

### ISC (In-situ Stimulation and Circulation Test)

Controlled hydraulic stimulation of existing fault zones  
Sub-project of the ETHZ-DUG-Lab project  
(SCCER-SoE, Swiss Competence Center for Energy Research – Supply of Electricity)

### LASMO (Large-Scale Monitoring)

Monitoring and characterisation of the geosphere

### LCS (Long-term Cement Studies)

Long-term interactions between cement solutions, porewaters and rock; cement injection experiment

### LTD (Long-term Diffusion)

Long-term diffusion of radionuclides

### MaCoTe (Material Corrosion Test)

Corrosion experiments (engineered barrier system components)

### MoDeRn (Monitoring Developments for Safe Repository Operation and Staged Closure)

Work package of the EU project for testing cable-free monitoring systems (TEM)

### Plug experiment (Engineering Studies and Demonstration of Repository Designs, previously an ESDRED sub-project)

<sup>1</sup> Sub-project of an EU project

Planned:

### HotBENT (High-Temperature Bentonite Project)

Investigations of the safety function of bentonite barriers under increased temperatures

### CIM (C-14/I-129 migration through aged cement)

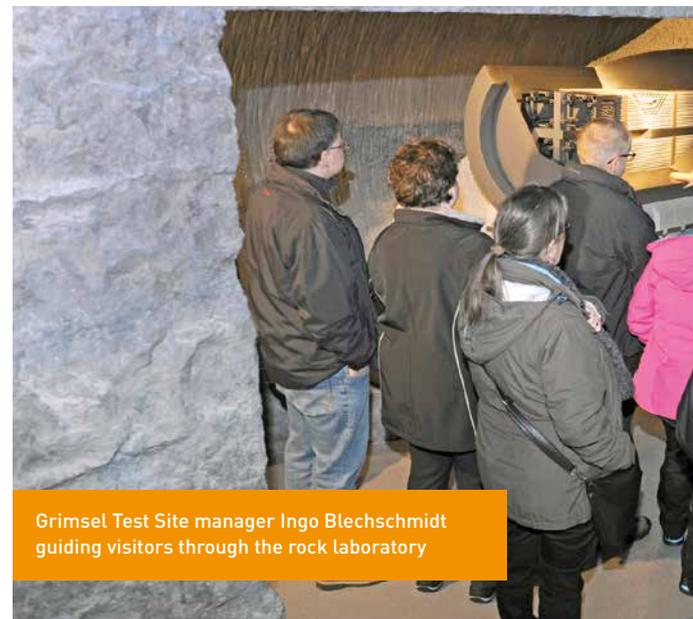
Testing the transport properties of C-14 and I-129 through cement barriers

## High safety standards

The annual inspection of the radiation controlled zone at the GTS by the responsible supervisory authority, the Federal Office of Public Health (FOPH), confirmed the high standard of the work with radioactive elements. Concepts for future experiments using radioactive tracers were also discussed with the FOPH and open questions addressed.

## Current experiments at the Grimsel Test Site

For the ISC project, ten boreholes were drilled at the beginning of the year and geophysical and hydrogeological investigations were carried out. The ISC project is led by the ETH Zürich and runs under the auspices of the Swiss Competence Center for Energy Research – Supply of Electricity (see box left). It provides baseline data for developing concepts for the use of deep geothermal energy and their future industrial-scale application. Three of the boreholes were equipped with fibre-optic systems for making deformation measurements, as well as systems for monitoring pressure and temperature. This was an important step towards preparing for the stimulation experiments planned for 2017.



Grimsel Test Site manager Ingo Blechschmidt guiding visitors through the rock laboratory

The in-situ radionuclide experiments of the CFM and LTD projects in the radiation controlled zone are currently in the long-term phase of monitoring and sampling. As part of the CFM experiment, initial characterisation work was carried out for the planned i-BET experiment (in-situ bentonite erosion test, see photo on page 28) in order to determine the experiment location. The experiment will examine the erosion of bentonite material under realistic in-situ conditions and should provide information on the long-term stability of individual engineered barrier components. Dismantling of the FEBEX experiment was completed in 2015 and the focus of activities in 2016 was on preparing reports on the field activities and laboratory studies. Various project reports and publications were produced or are still in preparation. Further dismantling and clean-up work was carried out in the FEBEX tunnel to prepare the location for follow-up experiments.

Further geochemical measurements and analyses were carried out in the LASMO project. At the same time, the ADUS borehole (borehole of Andra (France) from 1996) was characterised using hydraulic interval tests and hydrogeochemical analyses. Analysis of samples continued as part of

the MaCoTe corrosion experiment. The LCS experiment was completed as planned in 2016 and the results are being documented and published. The planned modifications to the instrumentation were carried out as part of the GAST project and continuous saturation began again in June.

### Preparing for new projects

Planning and preparation for the new projects CIM and HotBENT (see box left) began in 2016 and these should start in 2017. Concepts for the experiments have been prepared and the locations selected for the planned in-situ tests.

### RESEARCH BENEFITS FROM EXCHANGE OF KNOWLEDGE

Niels Giroud, Project Manager Geosciences



"I enjoy advising other researchers on technical questions", says Niels Giroud. "And I find international collaboration rewarding." He is currently advising a foreign waste management organisation on whether data from earlier experiments are suitable for a geological model. "The contact with external partners from around the world is stimulating", says Giroud, who has been working on various projects in the two Swiss rock laboratories since August 2013. Before joining

Nagra, he was involved in studying the geochemistry of geothermal systems, including some cases in Iceland. "I did not really change my area of technical expertise when I joined Nagra", comments Giroud. He continues to research the interactions between rock, water and gas. "Only the temperatures and permeabilities are somewhat different", he adds.

As part of the LCS experiment (see text-box on page 30), Giroud has been investigating the long-term interactions between cement solutions, porewaters and rock. Cement will be used as a backfill material in a future repository for low- and intermediate-level waste. After six years in the rock, the cement samples are now being recovered, the surrounding rock overcored and the cement and rock analysed. "This experiment has significantly improved our understanding of the interactions involved", he explains. "We now know much more about how cement behaves on the medium term in a natural environment, including how the pH value changes or what chemical reactions take place with the rock." For example, the high pH value of the cement waters can influence the water and gas permeabilities of the Opalinus Clay within the first few centimetres in the rock. The results will be used for future modelling studies.

"I find it important to exchange knowledge with other researchers", says Niels Giroud. Nagra works with institutes such as Empa, Eawag, the University of Bern and the Paul Scherrer Institute. "The exchange with other researchers inspires me in my work and ultimately serves as a kind of self-assessment", he adds.



## Nagra participation in experiments at the Mont Terri Rock Laboratory (FMT)

Experiments on characterisation of the Opalinus Clay have been underway in the international Mont Terri Rock Laboratory in Canton Jura since 1996. The rock laboratory gives Nagra the opportunity to investigate in detail the properties of the Opalinus Clay that are relevant for disposal of radioactive waste. 16 partner organisations from 8 countries are currently involved in the research projects and, in 2016, a new partner submitted an application to join the Mont Terri Consortium. The investigation programme is drawn up by a committee on which each partner is represented. The Mont Terri project is led by the Swiss Federal Office of Topography (swisstopo) and is supported by a "Commission stratégique". The interests of Canton Jura are represented by the "Commission de suivi".

## 20 years of the Mont Terri Rock Laboratory

The celebration in May of 20 years of the rock laboratory underlined the significance of the facility as a centre for international research on deep geological disposal where the scientific groundwork is laid for realising deep geological repositories. Guy Parmelin, a member of the Swiss Federal Council, attended the festivities, as did numerous national and cantonal politicians and guests from abroad. The national press reported extensively on the event and a series of overview articles in a special edition of the Swiss Journal of Geosciences documents the advances in science and technology achieved in the rock laboratory over the last 20 years.

## Focus of the work

Based on Nagra's multi-year research plan and recommendations made by the authorities, the focus of the work is on closer investigation of the properties of the Opalinus Clay host rock (FS-A, GC, HA-A, LT-A, RA experiments), diffusion of radionuclides in the Opalinus Clay (DR-B experiment), evolution of gas (FE-G), the corrosion of construction and container materials (IC-A) and

### "I WEAR THREE HATS IN MY JOB"

Olivier Leupin, Project Manager Materials Performance and Nagra delegate to the Mont Terri Project



"I wear three hats in my job", says the geochemist Olivier Leupin, who is deputy head of Nagra's research and development project. He also represents the interests of Nagra in the scientific Consortium of the Mont Terri Rock Laboratory. The Consortium currently has 16 partners from 8 countries.

Olivier Leupin helps to coordinate and plan the research programme in the rock laboratory. "I make sure that the research and development activities address the overarching questions of Nagra", he explains. These questions are documented in the new RD&D Plan (see page 23). "The topics are multifaceted and complex and we therefore work together with different research institutes such as the Paul Scherrer Institute."

Olivier Leupin's third responsibility is leading the project "Repository-induced influences". This covers all the processes that could influence the different safety barriers of a repository, including geochemical and microbial interactions between cement, bentonite or container materials in the near-field of a future repository. "These investigations provide the basis for demonstrating long-term safety", explains Leupin. But it is not only these complex processes that fascinate him: "It is exciting to find a creative and practical solution to a scientific question – like the XRF probe we are using for non-destructive detection of the diffusion of radionuclides."



the continuation of the long-term experiment on the interaction between Opalinus Clay and cement (CI experiment). The emplacement and heater experiment (FE-M) delivers a large volume of high-quality data on the evolution of the near-field of a deep geological repository.

As the space in the rock laboratory is somewhat limited for the planned experiments, it was decided to extend the facility up to 2019. The new gallery will almost double the available space.

### Detecting radionuclides easily

The long-term diffusion experiment DR-B measures the migration rate of iodide as a model nuclide for anionic nuclides. For the first time, a mobile, highly sensitive X-ray fluorescence probe originally developed for the Mars investigation programme is being used. This probe can measure the smallest concentrations of certain elements such as iodide. It operates non-destructively and with a high spatial resolution. The migration rates of all relevant radionuclides are required for the dose calculations in safety analyses.



The Mont Terri Rock Laboratory celebrated 20 years of research on 19<sup>th</sup> May.

### KEY EXPERIMENTS IN THE MONT TERRI ROCK LABORATORY

#### CI (Cement-Clay Interaction)

Mineralogical interaction between claystone and cement

#### DB (Deep Inclined Borehole through OPA)

Cored borehole through the Opalinus Clay

#### DR-A (Diffusion and Retention)

Diffusion and retention of radionuclides

#### DR-B (Long-term Diffusion Experiment)

Long-term diffusion experiment

#### FE (Full-Scale Emplacement Demonstration)

1:1 emplacement experiment for investigating the near-tunnel environment, with sub-projects:

FE-G (gas evolution in the FE experiment)

FE-M (monitoring of the FE experiment)

#### FS-A (Friction Properties of Opalinus Clay)

Laboratory investigations of hydromechanical properties of tectonically reactivated Opalinus Clay

#### GC (Geomechanical in situ Characterization)

Investigation and conceptualisation of tectonic fracture patterns

#### GD (Geochemical Data)

Analyses of geochemical data

#### HA-A (Hydraulic & Geophysical Parameter Variability)

Variability of the hydraulic and geophysical properties of the Opalinus Clay

#### HE-E (Heater Experiment)

Behaviour of the engineered barriers under the influence of heat

#### IC-A (Corrosion in Bentonite)

Corrosion of various types of metal in bentonite

#### LP-A (Long-term Monitoring of Pore Pressures)

Investigation of flow processes along water-conducting systems

#### LT-A (Properties Analyses Labtesting)

Laboratory investigations of the properties of Opalinus Clay

#### MA (Microbial Analyses)

Investigation of microbial reactions

#### MA-A (Modular Platform for Microbial Studies)

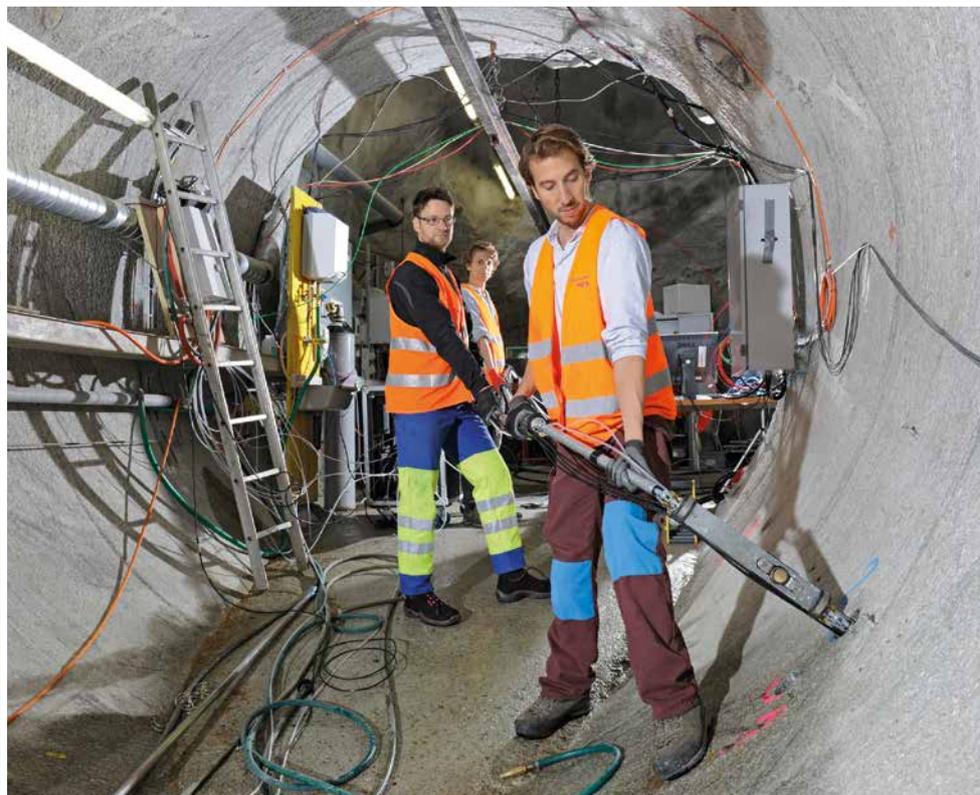
Microbial processes in the bentonite barrier

#### RA (Petrofabric and Strain Determination)

Structural analyses of the Opalinus Clay

#### WS-I (Investigation of Wet Spots)

Understanding the self-sealing of the EDZ (Excavation Damaged Zone) and tectonic faults



**RESEARCH IN THE ROCK LABORATORIES**

The international Mont Terri Research Project in Canton Jura is under the lead of the Swiss Federal Office of Topography (swisstopo). Nagra has been involved in the programme since its inception in 1996.

Nagra has operated the Grimsel Test Site since 1984. Scientists from around the world are carrying out research in the crystalline rock of the central Aar Massif. The laboratory is accessible year-round for the scientists working on the experiments.





The 2016 ISCO meeting: representatives of the Grimsel partner organisations meet every year to exchange information on their projects.

# International Services and Projects

With its continually increasing know-how, Nagra is in a strong position to effectively support its partner organisations. Capacity expanded in 2016 with the strengthening of the pool of experienced staff and broadening of the portfolio of services for clients in the nuclear field.

## Projects in Japan and South Korea

In Japan, the focus of the collaboration with our sister organisation NUMO was on two projects: preparing for the first phase of the site selection process and the Yokosuka demonstration project. Studies continued in the rock laboratories and on neotectonics with the Japan Atomic Energy Agency (JAEA). An exchange of information took place once again with RWMC on recent developments in nuclear waste management in Switzerland. Instrumentation and data analysis technologies were further developed with the Obayashi Corporation. In South Korea, the collaboration with KIGAM and KORAD covered various aspects of site exploration and selection and the planning of rock laboratories.

## Collaboration within Europe

Within Europe, several projects and consulting assignments were carried out for RWM (UK), together with work on the sealing of exploratory boreholes. The focus here was on further development of methods for quality assurance and control. A new, long-term framework agreement was also signed with ONDRAF/NIRAS (Belgium). Based on this, Nagra will provide support on the safety and feasibility demonstration of a deep geological repository, the design of the engineered safety barriers and the site selection process. The planning of experimental work in the Underground Research Laboratory at the Bukov site was the focus of the collaboration with SÚRAO/Czech Republic.

## Work in Switzerland

In Switzerland, support started for a project on the dismantling of the research reactor at the University of Basel. As part of the ongoing 3D seismic campaign, a tailor-made, practice-oriented training course on seismic exploration was conducted for our partners.

## Advisory activities continued

Our experts were also involved in a number of high-level advisory groups and steering committees, including the Geoscience Review Group on site selection for the Canadian high-level waste repository site (NWMO), the Steering Committee for the safety case for the operating licence (Posiva, Finland) and the international Technical Advisory Committee (NUMO, Japan).

### INTERNATIONAL SERVICES AND PROJECTS (ISP)

Nagra's ISP Division is responsible for projects with funding sources outside the Swiss national programme, as well as for the Grimsel Test Site. The activities cover a wide spectrum of projects in the radioactive waste management field – strategic programme planning, specification of waste inventories, site selection, characterisation and evaluation, repository design, safety case development, safety analyses, public communication, focused training and know-how build-up, as well as projects in other scientific and technical fields such as geothermal exploration.

# International collaboration

A regular exchange of information between Nagra and around 15 foreign partner organisations takes place within the framework of the various formal bilateral agreements. Joint projects are also carried out with several partners, either on a multilateral basis (e.g. rock laboratory projects in Switzerland and abroad) or together with international organisations. Joint projects are also run in the laboratories of various research institutes and on development of models and evaluation of databases. Besides the formal collaboration structure, international contacts have also generated a close network of personal relationships, which provide Nagra scientists with opportunities for informal discussion of technical issues with their peers.

Nagra's participation in the EU Framework Programmes represents an important component of its research and development activities. Collaboration with EU partners has been strengthened by Nagra's involvement in the "Implementing Geological Disposal of Radioactive Waste Technology Platform" (IGD-TP). Technical-scientific projects have started on several topics or are being discussed in working groups.

## Representation in advisory bodies

Nagra scientists continue to be represented in various advisory bodies and working groups – particularly in France, Japan, Canada and Sweden – and are able to benefit directly from the experience of sister organisations worldwide. Beyond the various specific joint projects, Nagra is also represented in more than ten working groups and projects of the OECD/NEA; these function as important discussion and exchange platforms on scientific-technical and societal aspects of waste disposal. Nagra employees are also involved regularly in expert groups of the IAEA. In 2016, Thomas Ernst was elected as Chairman of EDRAM, an association of senior-level staff from waste management organisations worldwide.

During the year, Nagra also took part in international meetings on the topic of geological disposal. Members of staff were invited to make presentations and were active on the programme com-

mittee of the "International Conference on Geological Repositories ICGR 2016". Nagra is organising the 7<sup>th</sup> "Clay Conference" in Davos in September 2017.

## Framework Research Programmes of the EU

The Framework Research Programmes of the EU are an important instrument for promoting collaboration on research projects within Europe and creating a European Research Area. The challenges faced by industry and society today should be solved together and not at an individual state level.

The 8<sup>th</sup> Framework Research Programme "Horizon 2020 – Research and Innovation" was launched in January 2014. The Euratom Programme on research and education in the nuclear field, which previously ran in parallel, has now been integrated into "Horizon 2020".

Based on a research agreement between Switzerland and the EU, Swiss scientists have been able since 2004 to participate fully in the EU Framework Programmes. In return, Switzerland makes a direct contribution to the total research budget.

The research projects in the area of deep geological disposal of radioactive waste allow Nagra to expand its technical knowledge base continuously and efficiently and to be instrumental in shaping important developments in Europe. The focus in 2016 was on a range of projects (see text-box right).

As part of the "Horizon 2020" programme, Nagra is participating in the projects "MoDeRn 2020" and "CAST" and also benefits from the projects "MIND" (microbiology) and "CEBAMA" (cement interactions).

### Results of the “DOPAS” project

Participating in the “DOPAS” project allowed Nagra to gain valuable access to the latest plugging and sealing designs for deep geological repositories being developed by waste management organisations that are close to, or have already submitted, licence applications and have well underpinned designs. A common rationale and methodological approach to addressing sealing and plugging issues was developed. Nagra benefitted particularly from being involved in the “Full Scale Seal” (FSS) experiment, a 1:1 full-scale seal constructed in a surface facility according to Andra’s proposed concept. This allowed Nagra to improve its knowledge base on the emplacement of granulated bentonite, which is particularly relevant for the Swiss high-level waste emplacement concept.

### 7<sup>TH</sup> EU FRAMEWORK RESEARCH PROGRAMME

#### CAST (Carbon 14 Source Term)

Investigation of the release rate and speciation of  $^{14}\text{C}$  due to corrosion of activated steels and Zircaloy and by leaching of exchange resins and graphite under repository-relevant conditions

Coordination: NDA (UK)

Participation: 33 organisations from 15 countries

Duration: 2013 – 2018

#### DOPAS (Full-Scale Demonstration of Plugs and Seals)

Investigation of the sealing concepts for the access structures of a geological repository for clay, salt and crystalline host rocks

Coordination: Posiva (Finland)

Participation: 14 organisations from 8 countries

Duration: 2012 – 2016

#### MoDeRn 2020 (Monitoring development for safe repository operation and staged closure 2020)

Preparing the basis for developing and implementing an efficient monitoring programme for deep geological repositories, taking into consideration the safety demonstration and the specific requirements of national programmes and local stakeholders

Coordination: Andra (France)

Participation: 28 organisations from 13 countries

Duration: 2014 – 2018



Trainees Carlos Soares from Canton Tessin and Berrak Firat Lüthi from Turkey working on the EU project “MoDeRn 2020” at the Grimsel Test Site.



Creating, coordinating, translating and editing texts, blogging, filming and photographing: Patrick Burgert, Benedikt Galliker, Linda McKinley and Alice Hellenbrandt from the Publications team (top left to bottom right), photographed by Anita Kendzia.

# Public outreach

## Communication and dialogue

Providing information that is factually correct and up-to-date and conducting open dialogue on a level suitable for the audience in question form the basis for building trust. Nagra's public relations activities are aimed at maintaining close contact with the public and providing them with comprehensive and transparent information tailored to different target groups. A wide range of communication tools and contact opportunities is used for this – the internet, brochures, films, media presence, guided tours of the rock laboratories, presentations and lectures, presence at regional trade fairs and discussion platforms.

## Exhibition: "Journey through time to a deep repository"

This new modular exhibition takes visitors on a virtual journey to a deep repository and appeals particularly to a younger audience. Equipped with virtual reality glasses, the visitor is transported into the future in a time-travel chair and can experience how a repository is constructed and filled with waste and how it is integrated into a region. The modular exhibition was supplemented in the second half of the year with a mobile variant with four chairs on a trailer. This can be used inside and outside for one-day events such as TecNights or training events.

## Trade fairs and guided tours – Nagra on location

In 2016, Nagra was present with its information stand at 24 regional trade fairs and markets. These events provided the opportunity for direct contact and exchange of opinions with the public. To accompany the seismic measurement campaigns in Zürich Nordost and Nördlich Lägern, Nagra also set up an information container in each of the regions.

A total of 4893 people visited the two rock laboratories – 1115 at the Grimsel Test Site and 3778 at the Mont Terri Rock Laboratory, which celebrated its 20<sup>th</sup> anniversary on 19<sup>th</sup> May. Nagra also organised four open-days at the Mont Terri Rock Laboratory for the interested public from the potential repository siting regions Südranden,

Zürich Nordost, Nördlich Lägern, Jura Ost and Jura-Südfuss and three open days at the Grimsel Test Site.

## Nagra's school programme

Four newsletters for teachers were distributed. Nagra was also invited to take part in TecDay events in various schools throughout Switzerland. These are organised on a regular basis and have proved to be very successful in making pupils aware of the fascination of natural science subjects. A working concept was prepared in order to inform schools about radioactive waste management. Based on this, a model of a repository for high-level waste was created and the landing page titled "Schools and young people" was expanded to include an interactive tool.

### "YOU COULD ALMOST SAY I AM PAID TO READ THE NEWSPAPER"

Franziska Stalder, Assistant, Media Office



"When I joined Nagra in 2005, we used to stick the newspaper articles into the daily press review by hand", recalls Franziska Stalder, who had returned to working life following family leave. The articles were then sent by fax to the subscribers. This was soon followed by an electronic version of the press review which was sent by e-mail. Today, Franziska Stalder checks the selection of articles made by an external monitoring company. "You could almost say I am paid to read the newspaper", she says smiling. Franziska Stalder also

deals with e-mails on a daily basis. She monitors the e-mail address info@nagra.ch and does a first check of incoming messages. Technical questions and other inquiries to Nagra are then forwarded to the appropriate person. She handles orders for information material such as school folders, brochures, flyers or DVDs herself. "I have a really varied job that allows me to work independently", she says.

Franziska Stalder also has a number of back-office tasks such as maintaining databases, for example for the annual report. She is also responsible for managing the stocks of all print products in the public relations department. She enjoys organising events such as media conferences, Nagra's "Future Day" for school-children and visitors' days in both the rock laboratories. "Depending on the event, I am responsible for invitations, registration, organising transport, selecting the venue and catering", she explains. "I really enjoy this kind of work." Not only that – Franziska Stalder also really appreciates the good working atmosphere at Nagra.



### **Nagra in the media spotlight**

In March, the television channel Tele Top featured a four-part series on nuclear facilities and how a region deals with these. 17 journalists from print, TV and radio took part in the media conference marking the start of the 3D seismic campaign in Zürich Nordost on 8<sup>th</sup> February. Nagra held its third annual media conference on 14<sup>th</sup> April and, on 21<sup>st</sup> June, a German radio station carried a detailed report on how German border communities view the Swiss repository plans. Five media releases were published in 2016; one of these addressed the call by ENSI for additional information.

In July, representatives of the media visited the geoelectric measurements being carried out in the Isenbuck/Berg area and a newspaper in Canton Wallis invited its readers to an open-day at the GTS. To accompany the submission of the applications for permits for the exploratory boreholes, media events were held in Jura Ost (Remigen) and Zürich Nordost (Marthalen) on 27<sup>th</sup> September. A further media event was held in Kaiserstuhl on 24<sup>th</sup> October to mark the start of the 3D seismic campaign in Nördlich Lägern.

### **Stronger social media presence, website reworked**

The new blog [www.nagra-blog.ch](http://www.nagra-blog.ch) has provided an insight into Nagra's daily work since the end of February 2016. Employees themselves write the contributions on topics such as field work, research, exhibitions and working with schools and young people. Some of the blog contributions are linked with the geosciences Facebook account of Nagra and thus reach a wider audience. The blog contributions are also circulated via online newspaper platforms.

The search function and navigation on the Nagra website – including the info bar – were made more efficient and user-friendly. The media and news section and the event calendar were also restructured to optimise orientation on the page.

### **Field work in words, photo and film**

In 2016, Nagra produced a range of print products on the ongoing field work, including a brochure updating the situation with Nördlich Lägern regarding geological investigations for Stage 3. A flyer was also produced for Nördlich Lägern with key information on the seismic measurements. At the end of September, Nagra also published a brochure on exploratory boreholes to coincide with the submission of the applications for the boreholes in Jura Ost and Zürich Nordost. An insert sheet with more detailed information was produced for each proposed drillsite in the two



regions. A flyer on the 2D seismic measurements was also produced for Jura Ost and Zürich Nordost. Photographs and film footage of the seismic measurements were also taken, including a short film with impressions from the campaigns in Jura Ost and Zürich Nordost; this was published on Nagra's YouTube channel. The 3D seismic campaigns and other field work such as shallow boreholes and 2D seismic measurements were the subject of numerous blog articles.

#### **"Stein" pocketbook: new edition**

The popular pocketbook "Stein" (stone) was updated and reprinted in April. A brochure was produced in August on the geology and groundwater of the Jura Ost siting region and, in November, a brochure on the shaft head facilities of a repository. A new page with interactive system sketches was also added under [www.nagra.ch](http://www.nagra.ch). Nagra produced a brochure in the middle of December to coincide with the publication of the 2016 Waste Management Programme. This was sent to around 13 000 subscribers in the German-speaking area. Two issues of "nagra info" were published and sent to subscribers, the one at the end of June with the focus on the 20-year anniversary of the Mont Terri Rock Laboratory. Two e-info newsletters were also distributed.

#### **Experience "Journey through time to a deep repository" at home**

The film "Journey through time to a deep repository" ("Zeitreise zum Tiefenlager") is now available in full length on Nagra's YouTube channel. The film can be viewed as a 360° video using a smartphone and the YouTube app. A special holder with optics such as the Google cardboard makes virtual reality glasses out of modern smartphones.

#### **Visit us on the internet:**

- [www.nagra.ch](http://www.nagra.ch)  
Comprehensive information for the public
- [www.nagra-blog.ch](http://www.nagra-blog.ch)  
Learn about our work
- [www.erdwissen.ch](http://www.erdwissen.ch)  
Geology blog coupled with social media





**EVENTS FOR THE PUBLIC**

2016 was a year full of events that gave people interested in Nagra's work the opportunity to learn more. The exhibition "Journey through time to a deep repository" with its virtual reality glasses was popular with both young and old and was extended to include a mobile version on a trailer. Nagra was available to answer questions from the public, including the seismic information containers in Zürich Nordost and Nördlich Lägern. A further highlight was the "Future Day" at Nagra which gives schoolchildren an exciting look into the world of waste management.



# Organisational structure 2016



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

"The safety of man and the environment is the main priority in the management of radioactive waste. Waste disposal should have no negative impacts on the human environment and also has to be compatible with the needs of the host region. It is personally of great importance to me that we should strive to meet this challenge in the future and approach it with the greatest sense of responsibility."

## **Executive Board of Nagra**

Top row, left to right: Dr. Tim Vietor, Division Head Safety, Geology & Radioactive Materials; Maurus Alig, Coordinator Major Project Sectoral Plan Stage 3 / General Licences; Reto Beutler, Division Head Finance, Controlling & Human Resources; Patrick Senn, Division Head Planning & Construction of Deep Geological Repositories

Bottom row, left to right: Dr. Markus Fritschi, Deputy CEO & Division Head Collaboration Sectoral Plan & Public Outreach; Dr. Thomas Ernst, Chief Executive Officer; Dr. Piet Zuidema, Overall Project Manager Sectoral Plan Stage 2



### Head office

At the end of 2016, 109 people were employed at Nagra's head office in Wetztingen (105 permanent employees and 4 part-time staff/temporary employees), corresponding to 97.6 full-time positions.

### Board of Directors and annual general meeting

The Board of Directors held four meetings to deal with ongoing business, with the focus on the Sectoral Plan process. The Board took note of the planned research and development work for 2017 and approved the required outline credit. Three closed meetings were also held on the 2016 Cost Study. The Technical Committee met four times and the Commission for Communication and Information held two meetings. The Finance Commission also met twice to consider the closing of the annual accounts for 2015, the budget for 2017 and the accumulated accounts. The annual general meeting of the members of the Nagra Cooperative took place on 20<sup>th</sup> June 2016 in Bern. The members approved the annual report and accounts for 2015 and Ronald Rieck was elected as the representative of Zwiilag on the Board of Directors; he replaces Walter Heep. On 28<sup>th</sup> November, an extraordinary general meeting was held to transfer the cooperative shares in Nagra from Alpiq Suisse SA to Alpiq AG.

### Further members of the Nagra management

From left to right: Dr. Andreas Gautschi, Chief Geoscientific Advisor; Dr. André M. Scheidegger, Deputy Coordinator Major Project Sectoral Plan Stage 3; Armin Murer, Deputy Division Head Collaboration Sectoral Plan & Public Outreach; Dr. Irina Gaus, Head of Research & Development; Dr. Stratis Vomvoris, Division Head International Services and Projects; Dr. Harald Maxeiner, Deputy Division Head Safety, Geology & Radioactive Materials



# Members of the Cooperative, Board of Directors, Commissions and Statutory Auditor

## 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

## Board of Directors

Corina Eichenberger  
Kölliken (AG)  
President of Nagra

Dr. Stephan W. Döhler  
Vice-President  
Axpo Power AG

Dr. Philipp Hänggi  
BKW Energie AG

Dr. Thomas Kohler  
Alpiq AG

Dr. Andreas Pfeiffer  
Kernkraftwerk Leibstadt AG

Dr. Michael Plaschy  
Kernkraftwerk Gösgen-  
Däniken AG

Ronald Rieck  
Zwilag Zwischenlager  
Würenlingen AG

Dr. Thierry Strässle  
Swiss Confederation

Peter Zbinden  
Erlenbach (ZH)  
Former CEO of AlpTransit  
Gotthard AG

## Technical Committee

Dr. Thomas Kohler  
Chairman  
Alpiq AG

## Finance Commission

Urs Helfer  
Chairman  
Axpo Power AG

## Commission for Communication and Information

Dr. Philipp Hänggi  
Chairman  
BKW Energie AG

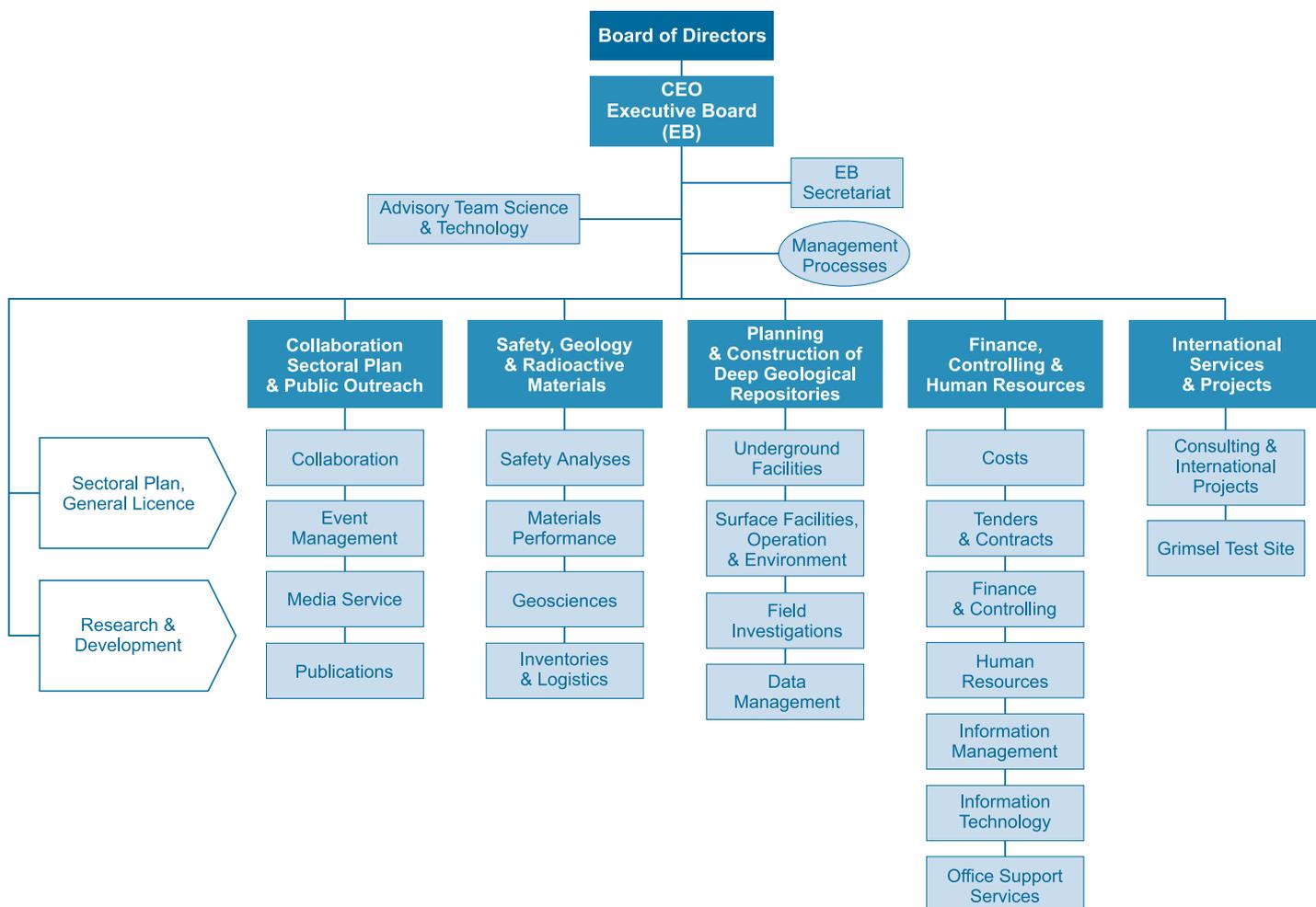
## Commission for Legal Issues

Hansueli Sallenbach  
Chairman  
Axpo Holding AG

## Statutory Auditor

PricewaterhouseCoopers AG  
Zürich

# Organigram of the head office up to 31<sup>st</sup> December 2016





# Annual financial statements 2016

# Comments on the annual financial statements for 2016

The current financial statements for 2016 were prepared in line with the provisions of the relevant Swiss legislation, in particular the articles on commercial accounting and financial reporting of the Code of Obligations for individual financial statements (Art. 957 to 962).

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

Total income increased by 3.4 million CHF compared to the previous year, mainly due to higher contributions by the members of the Cooperative (CHF 5.4 million), while net proceeds from sales of goods and services (CHF -1.9 million) and other operating income (CHF -0.1 million) decreased.

Project expenditure increased by CHF 1.1 million, mainly due to the seismic measurements in the siting regions Zürich Nordost and Nördlich Lägern.

Staff costs, other operational costs and depreciation increased by CHF 2.3 million due to the organisational restructuring with a view to Stage 3 of the Sectoral Plan process.

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

Wettingen, 5<sup>th</sup> April 2017



Dr. Thomas Ernst, Chief Executive Officer

# Balance sheet

Note	Assets	31.12.2016 CHF	31.12.2015 CHF
	<b>Current assets</b>		
	Cash and cash equivalents	15 639 717	13 136 310
C1	Trade receivables	268 573	1 477 417
	Due from third parties	216 305	1 332 091
	Due from members of the Cooperative	52 268	145 326
C2	Other current receivables	102 978	81 002
	Due from third parties	102 978	81 002
C3	Non-invoiced services	1 671 265	1 399 725
C4	Accrued income and prepaid expenses	1 138 921	2 065 475
	<b>Total current assets</b>	<b>18 821 454</b>	<b>18 159 929</b>
	<b>Capital assets</b>		
C5	Tangible fixed assets	1 610 261	1 515 535
	<b>Total capital assets</b>	<b>1 610 261</b>	<b>1 515 535</b>
	<b>Total assets</b>	<b>20 431 715</b>	<b>19 675 464</b>
	<b>Equity and liabilities</b>		
	<b>Current borrowed capital</b>		
C6	Trade payables	12 776 947	13 328 893
	Due to third parties	12 688 930	13 249 067
	Due to members of the Cooperative	88 017	79 826
	Other current liabilities	1 575 010	851 107
	Due to third parties	1 566 683	851 107
	Due to members of the Cooperative	8 327	-
C7	Advance payments received	1 521 686	2 015 793
C8	Deferred income and accrued expenses	4 418 072	3 339 671
	<b>Total current borrowed capital</b>	<b>20 291 715</b>	<b>19 535 464</b>
	<b>Total liabilities</b>	<b>20 291 715</b>	<b>19 535 464</b>
	<b>Equity</b>		
C9	Cooperative capital	140 000	140 000
	Annual profit (annual loss)	-	-
	<b>Total equity</b>	<b>140 000</b>	<b>140 000</b>
	<b>Total equity and liabilities</b>	<b>20 431 715</b>	<b>19 675 464</b>

Explanations page 56 ff.

# Profit and loss account

Note	1.1. – 31.12.2016		1.1. – 31.12.2015	
		CHF	CHF	CHF
<b>C10</b>	<b>Net proceeds from sales of goods and services</b>			
	Net proceeds from services for third parties	2 704 634		3 608 327
	Research contributions from third parties	159 743		962 432
	Net proceeds from services for Cooperative members	549 259		763 308
	<b>Total net proceeds from sales of goods and services</b>	<b>3 413 636</b>		<b>5 334 067</b>
<b>C11</b>	<b>Contributions of members of the Cooperative</b>			
	Contributions to administration costs	700 000		700 000
	Contributions to project expenditure	61 390 262		56 019 895
	<b>Total contributions of members of the Cooperative</b>	<b>62 090 262</b>		<b>56 719 895</b>
	<b>Other operating income</b>	<b>56 555</b>		<b>106 716</b>
	<b>Operating income (total output)</b>	<b>65 560 453</b>		<b>62 160 678</b>
<b>C12</b>	Cost of materials (project expenditure)	43 796 381		42 687 787
<b>C13</b>	Staff costs	18 190 207		16 562 673
<b>C14</b>	Other operational costs	3 304 377		2 676 052
<b>C5</b>	Depreciation and value adjustments on fixed assets	137 825		118 650
	<b>Operating result</b>	<b>131 663</b>		<b>115 516</b>
	Financial income	-153 498		-208 721
	Financial costs	157 706		181 618
	<b>Annual profit before taxes</b>	<b>127 455</b>		<b>142 619</b>
	<b>Direct taxes</b>	<b>127 455</b>		<b>142 619</b>
	<b>Annual profit (annual loss)</b>	<b>-</b>		<b>-</b>



# Notes to the financial statements

## A) General information

### Accounting legislation

The current financial statement was prepared in accordance with the provisions of Swiss law, in particular the articles on commercial accounting and financial reporting of the Code of Obligations for individual financial statements (Art. 957 to 962). These provisions have to be applied for annual financial statements that begin on or after 1<sup>st</sup> January 2015.

### Company, name, legal form and registered office

Nagra, National Cooperative for the Disposal of Radioactive Waste  
Hardstrasse 73, PO box 280, 5430 Wettingen.

### Type of audit

According to legal requirements (Art. 727a of the Code of Obligations), the annual financial statements of Nagra are subject to a limited audit. Nagra has selected opting-up for 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 5<sup>th</sup> April 2017 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 advance payments received 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 CHF 20k (one-off) and software below CHF 100k (one-off) are debited directly to the income statement.

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

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

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

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

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

**Payables**

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

**Provisions**

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

**C) Information, breakdowns and notes to the annual financial statements****C1) Trade receivables**

The decrease compared to the previous year (CHF 1209k) is due mainly to the unusually high contribution in 2015 from the MoDeRn 2020 project (Monitoring Developments for Safe Repository Operation) and an ongoing geothermal project at the Grimsel Test Site (together CHF 1032k).

As there were no identifiable credit risks as per the end of 2016, no value adjustment was made.

## C2) Other current receivables

Other current receivables include cash contributions for securing the centralised billing procedure of the Swiss Federal Customs Administration (CHF 10k) and for securing the fulfilment of a customer contract (EUR 20k). Other receivables amount to CHF 72k.

## C3) Non-invoiced services

Non-invoiced services consist of accrued internal services and third-party services for various projects.

## C4) Accrued income and prepaid expenses

Accrued income and prepaid expenses comprise the balance of the annual accounts (CHF 755k) by the members of the Cooperative, the pending reimbursement of PSI (CHF 97k), the prepayments for Suva 2017 (CHF 144k) and for rent for January 2017 (CHF 92k).

## C5) Tangible fixed assets

	Land and buildings	Office and workshop	Vehicles	Total
	CHFk	CHFk	CHFk	CHFk
<b>Acquisition value per 01.01.2015</b>	<b>1 825</b>	<b>570</b>	<b>653</b>	<b>3 048</b>
Additions		50		50
Disposals				
<b>Acquisition value per 31.12.2015</b>	<b>1 825</b>	<b>620</b>	<b>653</b>	<b>3 098</b>
Additions		152	80	232
Disposals			-87	-87
<b>Acquisition value per 31.12.2016</b>	<b>1 825</b>	<b>772</b>	<b>646</b>	<b>3 243</b>
<b>Accumulated depreciations per 01.01.2015</b>	<b>375</b>	<b>525</b>	<b>564</b>	<b>1 464</b>
Additions	30	57	31	118
Disposals				
<b>Accumulated depreciations per 31.12.2015</b>	<b>405</b>	<b>582</b>	<b>595</b>	<b>1 582</b>
Additions	30	69	39	138
Disposals			-87	-87
<b>Accumulated depreciations per 31.12.2016</b>	<b>435</b>	<b>651</b>	<b>547</b>	<b>1 633</b>
<b>Carrying value per 01.01.2015</b>	<b>1 450</b>	<b>45</b>	<b>89</b>	<b>1 584</b>
<b>Carrying value per 31.12.2015</b>	<b>1 420</b>	<b>38</b>	<b>58</b>	<b>1 516</b>
<b>Carrying value per 31.12.2016</b>	<b>1 390</b>	<b>121</b>	<b>99</b>	<b>1 610</b>

## C6) Trade payables

The largest position is the 3D seismic campaign in Nördlich Lägern carried out at the turn of the year.

## C7) Advance payments received

Advance payments received are for accrued internal services and third-party services for various projects. Because of the lower volume of third-party contracts, the advance payments received per 31.12.2016 (CHF 1522k) are lower than in the previous year (CHF 2016k).

**C8) Deferred income and accrued expenses**

With CHF 4418k, the deferred income and accrued expenses in the year of reporting is above the level of the previous year (CHF 3340k). This is mainly due to outstanding settlements for services (SFOE CHF 1177k). The deferral for liabilities from the 2008 social planning is omitted as all liabilities have been fulfilled.

**C9) Equity**

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

**C10) Net proceeds from sales of goods and services**

Net proceeds showed decreases in both the proceeds from third parties and from research projects and the proceeds from the NPP operators.

**C11) Contributions of the members of the Cooperative**

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

**C12) Cost of materials (project expenditure)**

The project expenditure is made up as follows:

<b>External services for:</b>	<b>2016</b>	<b>2015</b>
	CHFk	CHFk
Projects	30 774	26 285
Communication	2 124	3 401
Fees (ENSI, SFOE)	10 265	12 344
Travel costs	633	658
<b>Total</b>	<b>43 796</b>	<b>42 688</b>

**C13) Staff costs**

Staff costs, including social contributions, increased compared to the previous year by 9.8% to CHF 18 190k as part of the resource planning approved by the Board of Directors. The average staffing level in 2016 of 96.3 full-time positions (without temporary positions and apprenticeships) increased compared to the previous year by 4.5 full-time positions.

**C14) Other operational costs**

Other operational costs include rents and expenditure on property of CHF 1132k, expenditure on informatics of CHF 459k and costs for external management capacity in the Division Planning & Construction of Deep Geological Repositories of CHF 425k.

## D) Further information

### Liabilities towards pension schemes

As of 31.12 there were the following liabilities towards pension schemes	<b>31.12.2016</b>	<b>31.12.2015</b>
	CHF	CHF
Contribution statement December	188 838	168 327

### 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 accounts for 2016.

As of 31<sup>st</sup> December 2016 there were no guarantee obligations.

## Accumulated accounts

Note	Total income	Increase	Status	Increase	Status
		2015	31.12.2015	2016	31.12.2016
		CHF	CHF	CHF	CHF
	Swiss Confederation	1 618 356	37 270 973	1 773 135	39 044 108
	Axpo Power AG	12 345 009	281 689 190	13 528 940	295 218 130
	BKW Energie AG	5 992 550	131 171 107	6 566 917	137 738 024
	Kernkraftwerk Gösgen-Däniken AG	16 398 687	366 559 787	17 970 771	384 530 558
	Kernkraftwerk Leibstadt AG	19 665 293	414 297 390	21 550 499	435 847 889
	<b>Contributions for project expenditure</b>	<b>56 019 895</b>	<b>1 230 988 447</b>	<b>61 390 262</b>	<b>1 292 378 709</b>
	Contributions to administration costs	700 000	88 870 000	700 000	89 570 000
	<b>Contributions of Cooperative members to Nagra</b>	<b>56 719 895</b>	<b>1 319 858 447</b>	<b>62 090 262</b>	<b>1 381 948 709</b>
	<b>Contributions of GNW</b>	<b>-</b>	<b>65 265 331</b>	<b>-</b>	<b>65 265 331</b>
E1	<b>Total contributions</b>	<b>56 719 895</b>	<b>1 385 123 778</b>	<b>62 090 262</b>	<b>1 447 214 040</b>

Note	Total expenditure	Increase	Status	Increase	Status
		2015	31.12.2015	2016	31.12.2016
		CHF	CHF	CHF	CHF
	Geoscientific studies	5 590 415	194 579 942	9 554 794	204 134 736
	Nuclear technology and safety	1 580 565	49 877 087	1 357 903	51 234 990
	Radioactive materials	2 159 461	43 627 304	1 970 314	45 597 618
	Facility planning	891 236	31 419 581	525 224	31 944 805
	Generic (non-site-specific) work	3 586 406	105 747 452	3 223 571	108 971 023
	General programme costs	5 254 549	87 779 515	6 348 904	94 128 419
	Fees and compensation	6 893 963	60 063 413	5 137 486	65 200 899
	<b>L/ILW programme</b>	<b>25 956 595</b>	<b>573 094 294</b>	<b>28 118 196</b>	<b>601 212 490</b>
	Geoscientific studies	9 981 889	341 762 631	13 553 919	355 316 550
	Nuclear technology and safety	2 868 158	72 217 165	2 138 820	74 355 985
	Radioactive materials	706 851	26 309 449	845 708	27 155 157
	Facility planning	844 756	26 202 829	561 741	26 764 570
	Generic (non-site-specific) work	5 324 041	121 895 379	4 706 332	126 601 711
	General programme costs	4 887 636	72 928 064	6 338 239	79 266 303
	Fees and compensation	5 449 969	61 843 967	5 127 307	66 971 274
	<b>HLW programme</b>	<b>30 063 300</b>	<b>723 159 484</b>	<b>33 272 066</b>	<b>756 431 550</b>
E2	<b>Project expenditure for repository programmes</b>	<b>56 019 895</b>	<b>1 296 253 778</b>	<b>61 390 262</b>	<b>1 357 644 040</b>
	<b>Administration and general project expenditure</b>	<b>700 000</b>	<b>88 870 000</b>	<b>700 000</b>	<b>89 570 000</b>
	<b>Total expenditure for L/ILW and HLW programmes, administration and general project expenditure</b>	<b>56 719 895</b>	<b>1 385 123 778</b>	<b>62 090 262</b>	<b>1 447 214 040</b>

## 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 what 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 of the individual nuclear power plants of the members.

The contributions of the members in the total amount of CHF 62.1 million (CHF 56.7 million in the previous year) correspond to those in the income statement. Included is a contribution to administration costs in the total amount of CHF 0.7 million.

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

### **E2) Project-specific expenditure for the repository programmes**

The two repository programmes (HLW and L/ILW) 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 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, 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

## **Report of the Statutory Auditor on the annual financial statements for 2016**

As statutory auditor, we have audited the accompanying financial statements of Nagra, National Cooperative for the Disposal of Radioactive Waste, which comprise the balance sheet, income statement, cash flow statement and notes, for the year ended December 31, 2016.

### 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 error. Management is further responsible for selecting and applying appropriate accounting policies and making accounting estimates that are reasonable in the circumstances.

### Auditor's responsibility

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

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or 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 December 31, 2016 comply with Swiss law and the cooperative's articles of incorporation.

**Report on other legal requirements**

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

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

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

**PricewaterhouseCoopers AG**

Thomas Wallmer  
Audit expert  
Auditor in charge



Jonas Schwegler

Zürich, 5. April 2017



# Appendices

# Waste inventories and volumes

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

## Waste volumes at the end of 2016

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 2016. Not contained in the table are pre-conditioned raw wastes and waste packages prepared for processing in the Zwiilag plasma furnace, for example.

<b>Conditioned waste (31<sup>st</sup> December 2016, figures rounded)</b>	<b>Volume (m<sup>3</sup>)</b>	<b>Activity (Bq)</b>
<b>Nuclear power plants</b>	3 620	$3.0 \cdot 10^{15}$
<b>Zwiilag</b>	2 074	$7.9 \cdot 10^{18}$
<b>Federal Govt. interim storage facility</b> (waste from medicine, industry and research)	1 578	$1.2 \cdot 10^{16}$ <sup>1</sup>

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

<sup>1</sup> The clear increase in the activity for the Federal Government’s interim storage facility compared to last year is a result of waste (small cylinders) that had been treated up till now as raw waste and was not included in the figures for conditioned waste. After these wastes had been evaluated as suitable for disposal in 2016, they now appear in the inventory as conditioned waste.

### Predicted waste volumes and inventories for deep geological disposal

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

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

<sup>1</sup> 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

<sup>2</sup> Activity inventory for reference year 2075

# Publications in 2016

## **Nagra Technical Reports (NTB) / Nagra Work Reports (NAB)**

All NTBs can be downloaded from the Nagra website or are available in printed form at cost price. The NABs for Stage 2 of the Sectoral Plan process are also available as downloads.

The following reports were published in 2016:

ENSI-Nachforderung zum Indikator "Tiefenlage im Hinblick auf bautechnische Machbarkeit" in SGT Etappe 2: Zusammenfassende Darstellung der Zusatzdokumentation.  
NAB 16-41, July 2016

Prüfung der Lager- und Barrierenkonzepte.  
NAB 16-42, July 2016

Geomechanische Unterlagen: ENSI-Nachforderung zum Indikator "Tiefenlage im Hinblick auf bautechnische Machbarkeit" in SGT Etappe 2.  
NAB 16-43, July 2016

Standortspezifische geologische Modelle und geologische Gefährdungsbilder.  
NAB 16-44, July 2016

Projektkonzepte für die Lagerkammern und Versiegelungsstrecken und deren Bewertungen.  
NAB 16-45, July 2016

Vortriebs- und Sicherungskonzepte für die Profile F, K09, K04, K04a und D (Ergänzende Unterlagen zu NAB 16-45).  
NAB 16-46, July 2016

High-level waste repository-induced effects,  
NTB 14-13, October 2016

Low- and intermediate-level waste repository-induced effects, NTB 14-14, October 2016

Generische Beschreibung von Schachtkopf-anlagen (Nebenzugangsanlagen) geologischer Tiefenlager. NTB 16-08, October 2016

Entsorgungsprogramm 2106 der Entsorgungspflichtigen. NTB 16-01, December 2016

The Nagra Research, Development and Demonstration (RD&D) Plan for the Disposal of Radioactive Waste in Switzerland. NTB 16-02, December 2016

Production, transport and consumption of gases in deep geological repositories according to the Swiss disposal concept. NTB 16-03, December 2016

Modelling of Gas Generation in Deep Geological Repositories after Closure. NTB 16-04, December 2016

An assessment of the possible fate of gas generated in a repository for low- and intermediate-level waste. NTB 16-05, December 2016

The lists of the Technical and Work Reports can be found on the website ([www.nagra.ch](http://www.nagra.ch) → Infocorner → Publications / Downloads → Technical Reports → Full lists).

A series of print products for the wider public was also produced in 2016. They are generally not available in English. All brochures, factsheets and annual reports can be downloaded from the Nagra website as pdfs.

# Glossary / Abbreviations

## **AG SiKa**

Cantonal Working Group on Safety

## **Alpiq AG**

[www.alpiq.ch](http://www.alpiq.ch)

## **Andra**

Agence nationale pour la gestion des déchets radioactifs

[www.andra.fr](http://www.andra.fr)

## **ATW**

Alpha-toxic waste

## **Axpo**

[www.axpo.com](http://www.axpo.com)

## **BGR**

Federal Institute for Geosciences and Natural Resources

[www.bgr.bund.de](http://www.bgr.bund.de)

## **BKW Energie AG**

Formerly Bernische Kraftwerke AG

[www.bkw.ch](http://www.bkw.ch)

## **BMUB**

German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

[www.bmub.bund.de](http://www.bmub.bund.de)

## **DETEC**

Swiss Federal Department for the Environment, Transport, Energy and Communications

[www.uvek.admin.ch](http://www.uvek.admin.ch)

## **Eawag**

Swiss Federal Institute of Aquatic Science and Technology

[www.eawag.ch](http://www.eawag.ch)

## **EDRAM**

International Association for Environmentally Safe Disposal of Radioactive Materials

[www.edram.info](http://www.edram.info)

## **EGT**

Expert Group on Nuclear Waste Disposal

[www.egt-schweiz.ch](http://www.egt-schweiz.ch)

## **Empa**

Swiss Federal Laboratories for Materials Science and Technology

[www.empa.ch](http://www.empa.ch)

## **ENSI**

Swiss Federal Nuclear Safety Inspectorate

[www.ensi.ch](http://www.ensi.ch)

## **Euratom**

European Community research and training programme

<https://ec.europa.eu/programmes/horizon2020/>

## **FMT**

Mont Terri Rock Laboratory – rock laboratory in Opalinus Clay located near St-Ursanne, Canton Jura.

[www.mont-terri.ch](http://www.mont-terri.ch)

## **GTS**

Grimsel Test Site – Nagra's underground laboratory in crystalline rock on the Grimsel Pass, Canton Bern

[www.grimsel.com](http://www.grimsel.com)

## **HLW**

Vitrified high-level waste from reprocessing

## **Horizon 2020**

Framework Programme for Research and Innovation

<https://ec.europa.eu/programmes/horizon2020/>

## **IAEA**

International Atomic Energy Agency, Vienna

[www.iaea.org](http://www.iaea.org)

## **IGD-TP**

Implementing Geological Disposal of Radioactive Waste Technology Platform (European Commission, Research & Innovation)

[www.igdtp.eu](http://www.igdtp.eu)

## **ILW**

Long-lived intermediate-level waste

## **ISCO**

International Steering Committee, Grimsel Test Site

## **JAEA**

Japan Atomic Energy Agency

[www.jaea.go.jp](http://www.jaea.go.jp)

## **KES**

Cantonal Expert Group on Safety

## **KIGAM**

Korea Institute of Geoscience and Mineral Resources

[www.kiagm.re.kr](http://www.kiagm.re.kr)

## **KORAD**

Korea Radioactive Waste Agency

[www.korad.or.kr](http://www.korad.or.kr)

## **KWO**

Kraftwerke Oberhasli AG

[www.grimselstrom.ch](http://www.grimselstrom.ch)

## **L/ILW**

Low- and intermediate-level waste

## **MIR**

Radioactive waste from medicine, industry and research

## **MIRAM**

Model Inventory of Radioactive Materials

## **NAB**

Nagra Work Report

**NDA**

Nuclear Decommissioning Authority  
[www.nda.gov.uk](http://www.nda.gov.uk)

**NEA**

Nuclear Energy Agency of the OECD,  
Paris  
[www.oecd-nea.org](http://www.oecd-nea.org)

**NSC**

Swiss Federal Nuclear Safety  
Commission  
[www.bfe.admin.ch/kns](http://www.bfe.admin.ch/kns)

**NTB**

Nagra Technical Report:  
scientific publication series

**NUMO**

Nuclear Waste Management  
Organization of Japan  
[www.numo.or.jp](http://www.numo.or.jp)

**NWMO**

Nuclear Waste Management  
Organization  
[www.nwmo.ca](http://www.nwmo.ca)

**Obayashi**

Obayashi Corporation  
[www.obayashi.co.jp](http://www.obayashi.co.jp)

**OECD**

Organisation for Economic Cooperation  
and Development, Paris  
[www.oecd.org](http://www.oecd.org)

**ONDRAF/NIRAS**

Organisme national des déchets  
radioactifs et des matières fissiles  
enrichies / Nationale instelling voor  
radioactief afval en verrijkte  
spleijstoffen  
[www.ondraf.be](http://www.ondraf.be) / [www.niras.be](http://www.niras.be)

**Posiva**

Posiva Oy  
[www.posiva.fi](http://www.posiva.fi)

**PSI**

Paul Scherrer Institute, Villigen  
[www.psi.ch](http://www.psi.ch)

**RD&D**

Research, Development &  
Demonstration

**RWM**

Radioactive Waste Management  
[www.nda.gov.uk/rwm/organisation/  
rmb](http://www.nda.gov.uk/rwm/organisation/rmb)

**RWMC**

Radioactive Waste Management  
Funding and Research Center  
[www.rwmc.or.jp](http://www.rwmc.or.jp)

**SF**

Spent fuel assemblies

**SFOE**

Swiss Federal Office of Energy  
[www.bfe.admin.ch](http://www.bfe.admin.ch)

**SKB**

Svensk Kärnbränslehantering AB  
[www.skb.se](http://www.skb.se)

**SÚRAO**

Radioactive Waste Repository Authority,  
Czech Republic  
[www.surao.cz](http://www.surao.cz)

**STENFO**

Decommissioning and Waste Disposal  
Funds  
[www.stenfo.ch](http://www.stenfo.ch)

**Swissnuclear**

Nuclear energy section of Swisselectric  
[www.swissnuclear.ch](http://www.swissnuclear.ch)

**Swisstopo**

Swiss Federal Office for Topography;  
project manager of the Mont Terri Rock  
Laboratory  
[www.swisstopo.admin.ch](http://www.swisstopo.admin.ch)

**TWI**

The Welding Institute, UK  
[www.twi-global.com](http://www.twi-global.com)

**Zwilag**

Centralised interim storage facility of the  
Swiss nuclear power plants for all  
categories of waste (Würenlingen, Canton  
Aargau)  
[www.zwilag.ch](http://www.zwilag.ch)

Explanations of the abbreviations for the  
experiments at the Grimsel Test Site and  
the Mont Terri Rock Laboratory can be  
found in the text-boxes on pages 30  
and 33.

**FURTHER INFORMATION:**

**Internet portal on nuclear energy**  
[www.kernenergie.ch](http://www.kernenergie.ch)

**Nuklearforum Schweiz**  
[www.nuklearforum.ch](http://www.nuklearforum.ch)

**Radioactive waste (SFOE)**  
[www.bfe.admin.ch/radioaktiveabfaelle/](http://www.bfe.admin.ch/radioaktiveabfaelle/)

**Technical Safety Forum**  
[www.ensi.ch/en/technical-safety-forum/](http://www.ensi.ch/en/technical-safety-forum/)

**Forum VERA**  
[www.forumvera.ch](http://www.forumvera.ch)

**Photo credits**

AMOI Sàrl  
Pages 32, 33

Anita Kendzia  
Pages 40, 44 (bottom left)

Beat Müller  
Pages 7 (centre), 22, 26 (bottom),  
27 (top, bottom left)

Benedikt Galliker  
Page 4 (centre; bottom left), 5 (centre left),  
6 (centre), 13, 19, 24, 26 (top), 27 (bottom right),  
32 (left), 34 (top), 35 (top, centre), 44 (top left,  
bottom right), 45 (top right, bottom right)

Christoph Gmuender  
Pages 20, 21

©Comet Photoshopping, Dieter Enz  
Page 4 (top right), 7 (bottom), 10, 28, 30, 31, 34  
(bottom), 35 (bottom), 36

Franziska Stalder / Marisa Brauchli  
Page 44 (top right, centre right), 45 (top centre)

Hanspeter Weber  
Page 7 (top)

Hansruedi Fisch  
Page 4 (bottom right)

Jutta Lang  
Page 43

Maria Schmid  
Pages 2, 3, 4 (top left), 5 (top, bottom), 15, 31, 41,  
42, 46, 47

Marisa Brauchli  
Page 39

matho c/o Imagepoint  
Page 8

Nagra  
Page 6 (top, bottom), 7 (bottom)

National Cooperative  
for the Disposal of  
Radioactive Waste

Hardstrasse 73  
Postfach 280  
CH-5430 Wettingen

Tel: 056 437 11 11  
Fax: 056 437 12 07

[info@nagra.ch](mailto:info@nagra.ch)  
[www.nagra.ch](http://www.nagra.ch)  
[www.nagra-blog.ch](http://www.nagra-blog.ch)

**nagra** ● **we care**