

# **RADIOACTIVE WASTE MANAGEMENT PROGRAMMES IN OECD/NEA MEMBER COUNTRIES**

## **SWITZERLAND**

### **NATIONAL NUCLEAR ENERGY CONTEXT**

Commercial use of nuclear power in Switzerland began in 1969 and, by 1984, 5 nuclear power units were connected to the electricity grid. Together, they generate approximately 25 TWh of electricity each year, i.e. around 40% of the total electricity produced.

Additionally, in June 2008 a general licence application was submitted for a new nuclear power plant (NPP) near the site of the Gösgen NPP. Further general licence applications to replace the older NPPs of Beznau and Mühleberg were submitted in December 2008.

A new Nuclear Energy Act was approved by Parliament in March 2003 and came into force in 2005. Its main provisions are:

- No limitation on the operating lifetime of the NPPs, other than on the basis of safety considerations.
- An optional national referendum for the general licence for new nuclear facilities (including radioactive waste repositories).
- A 10-year moratorium on reprocessing of spent fuel, beginning in July 2006.
- Responsibility of the waste producers for the management and disposal of their wastes.
- Responsibility of the Federal State for the management of radioactive waste arising from medicine, industry and research.
- Disposal of all radioactive wastes in deep geological repositories.
- Broad consultation within the framework of the site selection process.
- Securing the necessary financial resources in two independent funds for nuclear facility decommissioning and waste disposal.

According to the new legislation, radioactive waste disposal is expected, in principle, to take place in Switzerland, although disposal within the framework of a multinational project may be allowed as an exception, provided strict conditions are fulfilled.

## SOURCES, TYPES AND QUANTITIES OF WASTE

### WASTE management concept

The nuclear waste management concept in Switzerland envisages two repositories, one for low- and intermediate-level waste (L/ILW) and the other for spent fuel (SF), high-level waste (HLW) and long-lived intermediate-level waste (ILW).

For planning purposes, a model waste inventory (MIRAM) of all expected or projected waste arisings has been developed and is periodically updated. In addition, the operators of the NPPs and waste management facilities, together with the *National Cooperative for the Disposal of Radioactive Waste (Nagra)*, have developed an electronic database, ISRAM, which includes a detailed description of all waste packages and their contents and thus provides a complete and detailed account of the radioactive wastes currently existing in Switzerland.

### WASTE volumes

The majority of radioactive wastes arising in Switzerland come from nuclear electricity production; a more detailed breakdown of the expected and projected arisings of the different waste types can be found below. These are based on the model inventory of all radioactive wastes estimated to arise from a 50-year operating lifetime for the existing NPPs and from their subsequent decommissioning. The waste volumes from medicine, industry and research assume a period of collection up to 2050.

The values given below are for the wastes packaged in disposal containers ready for emplacement in the repositories; the values in brackets are the volumes of conditioned wastes, as delivered to the disposal facility, before packaging into disposal containers.

### Low- and intermediate-level waste

L/ILW consists of operational waste from the NPPs, waste from medicine, industry and research and waste from the decommissioning and dismantling of the NPPs and nuclear research facilities. According to current estimates, the total volume of L/ILW will amount to 90,370 m<sup>3</sup> (66,355 m<sup>3</sup>). Of this, 33,090 m<sup>3</sup> (27,595 m<sup>3</sup>) are operational and decommissioning wastes from medicine, industry and research (this figure includes a reserve of 12,000 m<sup>3</sup> mainly to cover wastes from large research facilities), 26,140 m<sup>3</sup> (7,655 m<sup>3</sup>) represent operational waste from the NPPs (including exchangeable reactor internals such as control rods, etc.) and 28,920 m<sup>3</sup> (28,885 m<sup>3</sup>) are expected from the decommissioning of the five existing NPPs and the waste treatment installations (plasma incinerator) at the ZWILAG centralised interim storage facility. 2,220 m<sup>3</sup> of waste are assumed to arise from the facility for encapsulation of spent fuel elements and high-level waste.

### Spent fuel, high-level and long-lived intermediate-level wastes

A total of around 3,575 tonnes HM of spent fuel is expected from the five reactors currently in operation, assuming a 50-year operating lifetime. The contracts between the Swiss NPP operators

and reprocessing companies in France and the United Kingdom cover approximately 1,200 tonnes HM of spent fuel. For planning purposes, this is assumed to be the total amount that will be reprocessed although, in principle, reprocessing may be resumed after the current moratorium has expired. This scenario will result in 6,595 m<sup>3</sup> (1,135 m<sup>3</sup>) of spent fuel elements (encapsulated in disposal containers), about 730 m<sup>3</sup> (115 m<sup>3</sup>) of vitrified high-level waste and 1,320 m<sup>3</sup> (200 m<sup>3</sup>) of long-lived ILW from reprocessing.

Considering an extension – from 50 to 60 years – of the operation time of existing NPPs , as well as the building of new NPPs which is currently under discussion in Switzerland, “overall waste volumes” are being used for planning purposes, i.e. around 20,000 m<sup>3</sup> of spent fuel and vitrified high-level waste, 7500 m<sup>3</sup> of intermediate-level waste and 200,000 m<sup>3</sup> of low and intermediate-level waste.

## **RADIOACTIVE WASTE MANAGEMENT POLICIES AND PROGRAMMES**

### **WASTE management policies**

The strategy followed by the NPP operators includes both reprocessing and storage of spent fuel for later reprocessing and direct disposal. Reprocessing is carried out abroad, but the resulting radioactive waste has to be returned to Switzerland. The Nuclear Energy Act contains a moratorium on the shipment of spent fuel for reprocessing for a period of 10 years starting in July 2006.

The disposal of radioactive waste is based on a concept defined by an expert group. Following a long observation phase, the underground repository of radioactive waste is sealed and placed under the authority of the state.

Switzerland's disposal concept foresees two deep geological repositories: one for low and intermediate level waste, and one for high-level waste. For both waste categories it would also be possible to construct and operate two deep geological repositories at the same site, as long as this is technically feasible and safety can be guaranteed. Because of the necessary cooling time prior to disposal, the repository for SF/HLW will not be needed for several decades. The option of disposing of wastes abroad within the framework of a bilateral or multilateral project is being kept open, but not actively pursued.

Since no repository is available as yet, all radioactive wastes are transferred to interim storage facilities. Each NPP has interim storage capacity for its own operational waste and some of its spent fuel. The radioactive waste from medicine, industry and research is stored at a federal interim storage facility. A centralised interim storage facility for all types of radioactive waste, particularly for vitrified high-level reprocessing waste and spent fuel, is now in operation (see below).

Switzerland has ratified the IAEA's Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

## **PROGRAMMES and projects**

### ***WASTE conditioning***

The Swiss Law stipulates that the use of radioactive matter must result in as little waste material as possible. All waste material that is produced despite this minimisation requirement first has to be conditioned (i.e. brought into a stable state) and packed in suitable receptacles. The conditioning of radioactive waste is supervised by the Swiss Federal Nuclear Safety Inspectorate (ENSI).

L/ILW is reduced in volume by compaction, incineration or melting, treated with a leach-resistant bonding agent, usually cement but also bitumen or polystyrene in some cases, and solidified in containers, generally 200-litre drums but also larger containers. Long-lived ILW is conditioned in a similar way. Both vitrified HLW in its thin steel fabrication containers and spent fuel will be encapsulated in massive canisters for disposal.

### ***INTERIM storage***

As noted above, each NPP already stores its own operational waste. Wastes arising from medicine, industry and research are the responsibility of the Federal State and have been stored since 1992 in a federal storage facility (Bundeszwischenlager BZL) operated by the Paul Scherrer Institute (PSI). The facility has capacity for 4,200 m<sup>3</sup> of waste (including future storage capacity).

A centralised interim storage facility (Zentrales Zwischenlager, ZZL, operated by ZWILAG), owned by the NPPs, has been fully operational since 2002. It is located in Würenlingen, adjacent to the PSI site, and features a hall for dry storage of 200 casks containing spent fuel and vitrified HLW, as well as a storage building for ILW with a capacity of 11,000 m<sup>3</sup>. A hall for L/ILW waste, with a capacity of 27,000 m<sup>3</sup>, will be available for the storage of decommissioning waste from the NPPs. ZWILAG also has facilities for sorting and decontamination of materials and for the conditioning of waste, as well as a plasma furnace for incineration and melting of L/ILW. ZWIBEZ, an interim storage facility located at the Beznau NPP, can accommodate 46 storage casks for HLW and spent fuel. An additional interim wet storage facility was commissioned in 2008 at the Gösgen NPP, extending the on-site storage capacity from 600 to 1600 spent fuel elements. Sufficient interim storage capacity is thus available for all the waste arising from the present NPPs during their operating lifetime.

### ***DISPOSAL***

According to the nuclear energy legislation, all types of waste must be disposed of in deep geological repositories. Long-term safety of the repository must be assured without the need for active post-closure monitoring or control.

The legislation requires a demonstration of the feasibility of safe and permanent disposal of radioactive waste in Switzerland. For low- and intermediate-level waste, such a demonstration was formally accepted by the Federal Government in 1988. Acceptance was based on a study of the technical feasibility and safety of the disposal concept, entitled "Project Gewähr 1985", which was prepared by Nagra and reviewed by the regulatory authorities. Nagra's site selection

procedure for a L/ILW repository began in the 1970s. In 1993, Nagra proposed Wellenberg in Canton Nidwalden as the repository site and, in 1994, an application for a general licence was submitted. The review of licence application by the federal nuclear safety authorities came to a positive conclusion, but the granting of the mining concession required by cantonal legislation was rejected by the voters of Canton Nidwalden in a cantonal referendum (the siting community of Wolfenschiessen voted in favour of the concession). A stepwise approach was subsequently proposed and an application for an exploratory drift only (for a modified repository project) was submitted in 2001. Once again, the population of Canton Nidwalden rejected the concession application in September 2002, with the community of Wolfenschiessen again voting in favour of the project. Consequently, the project was abandoned. A new site selection process is currently underway (see below).

For the disposal of spent fuel, HLW and long-lived ILW, a demonstration of disposal feasibility (Entsorgungsnachweis) was approved by the Federal Government in June 2006. This demonstration is based on a deep geological repository concept with in-tunnel emplacement of SF/HLW and caverns for long-lived ILW for a project with Opalinus Clay as the host rock. After an initial broad survey of options in the late 1970s, early siting studies focused on the crystalline basement of Northern Switzerland, but data on the overlying formations were also collected. The results of the investigations were integrated into the assessment carried out within the framework of "Project Gewähr 1985". While the Federal Government accepted the demonstration of the safety and engineering feasibility of constructing a repository for HLW and long-lived ILW in the crystalline basement of Northern Switzerland, it had some reservations with respect to siting and was not convinced that sufficiently extensive blocks of rock with the required properties could be found. It therefore requested that the investigations be extended to include sedimentary formations. For the crystalline basement, the regional investigations were finalised and a comprehensive evaluation submitted to the authorities in 1994. Further studies identified the region of the Mettau valley in the canton of Aargau as a potential location for any further investigation of the crystalline basement.

In a stepwise process initiated in the mid-1980s with the safety authorities and their experts, several options in sedimentary rock were considered. To demonstrate the feasibility of disposal, the Opalinus Clay of the Zürcher Weinland in the northern part of the Swiss Plateau was finally selected and a detailed characterisation programme was carried out. This included a 3D seismic campaign, the drilling of an exploratory borehole, experiments in the Opalinus Clay as part of the international research programme in the Mont Terri Rock Laboratory and the evaluation of information on Opalinus Clay from several other sources. Based on the results of these investigations, the demonstration of disposal feasibility (Entsorgungsnachweis) was submitted by Nagra to the Federal Government in December 2002 and approved in June 2006.

The legislation requests the site selection process for both L/ILW and HLW repositories to be defined in a sectoral plan procedure within the framework of existing spatial planning legislation. Site selection should be based primarily on technical criteria, with the main emphasis on safety, but must also address land use planning and socio-economic aspects. The conceptual part of the Sectoral Plan for Deep Geological Repositories, defining a three-stage site selection process and a series of site selection criteria as well as the respective roles and responsibilities of the parties involved, was prepared by the federal authorities under the lead of the Swiss Federal Office of Energy (SFOE). Following a broad consultation process, it was approved by the Federal Government on 2nd April 2008.

The Sectoral Plan process can be described as follows: At stage 1, the waste producers propose geologically suitable siting areas based on safety criteria and justify the selection in a

report addressed to the Federal Government. This is followed by inventorying of the spatial planning situation and a safety review. At the same time, a cantonal commission is established and the groundwork prepared for regional participation.

Together with the siting Cantons, a spatial planning assessment of the siting areas proposed in stage 1 is undertaken in stage 2 and socio-economic studies are prepared together with the siting regions. With the involvement of the siting regions, the waste producers also draw up proposals for the siting of the surface infrastructure. For this, they carry out provisional quantitative safety analyses and a safety-based comparison before identifying at least two sites each for HLW and L/ILW.

In stage 3, the remaining sites are to be investigated in depth with a view to site selection and preparation of an application for a general licence. The repository projects are concretised together with the siting regions and socio-economic implications are analysed in greater depth. The siting regions propose projects for regional development and prepare the background information for deciding on any compensation measures and for monitoring of socio-economic and environmental impacts. Compensation measures will be negotiated and made transparent in stage 3. The waste producers will finally submit applications for a general licence (one each for HLW and L/ILW or one for a so-called “combined repository”).

For stage 1 of the Sectoral Plan process, Nagra (on behalf of the waste producers) submitted a list of potential geological siting areas to the authorities in October 2008. Siting areas for the L/ILW repository include:

- Südranden (Canton Schaffhausen) with the host rock Opalinus Clay and its confining units
- Zürcher Weinland (Cantons Zürich, Thurgau) with the host rocks Opalinus Clay and the claystone sequence 'Brauner Dogger' with their confining units
- North of Lägeren (Cantons Zürich, Aargau) with the host rocks Opalinus Clay and the claystone sequence 'Brauner Dogger' with their confining units
- Bözberg (Canton Aargau) with the host rock Opalinus Clay and its confining units
- Jura-Südfuss (Cantons Solothurn, Aargau) with the host rocks Opalinus Clay and its confining units and the Effingen Beds
- Wellenberg (Cantons Nidwalden, Obwalden) with the host rock marl formations of the Helveticum

Siting areas for the HLW repository include:

- Zürcher Weinland (Cantons Zürich, Thurgau) with the host rock Opalinus Clay and its confining units
- North of Lägeren (Cantons Zürich, Aargau) with the host rock Opalinus Clay and its confining units

- Bözberg (Canton Aargau) with the host rock Opalinus Clay and its confining units

In three of the geological siting areas (Zürcher Weinland (Cantons Zürich, Thurgau), North of Lägeren (Cantons Zürich, Aargau) and Bözberg (Canton Aargau), it would be possible, in principle, to site the L/ILW and HLW repositories together as a so-called "combined repository".

Following the review by the authorities and extensive public consultation, the Federal Government approval is expected around 2011.

## **RESEARCH and development**

The Federal State has the duty to guarantee independent research concerning radioactive waste disposal. For this purpose it created a research program covering its needs in this field until 2013. In this program, the SFOE manages the projects of human and social sciences and ENSI the regulatory security research.

Extensive R&D programmes are run by Nagra to provide the geological, engineering and scientific information required for developing the L/ILW and SF/HLW/ILW repository projects. Nagra is responsible for planning and funding R&D projects that are carried out to a large extent by external contractors. In addition to site-specific investigations and work in generic underground research laboratories (URLs), extensive programmes are carried out at PSI (co-funded by the Swiss Government), universities and various research companies and institutes in Switzerland and abroad.

Nagra has close contacts with sister organisations in other countries and much R&D work is undertaken through collaborative, co-funded projects, in part within the framework of European Commission research programmes. International collaboration is particularly important in the studies carried out in underground rock laboratories. At the Grimsel Test Site, which is located in crystalline rock in the Swiss Alps, several experiments are underway in collaboration with partners from various countries; some are also partially funded by the European Community.

The Mont Terri Rock Laboratory, located in the Opalinus Clay of the Jura Mountains, is an international project headed by the Swiss Federal Office of Topography (swisstopo), with partners from several countries. A number of experiments are co-financed by the European Community. The present programme consists of investigations aimed at obtaining information on the hydrogeological, geochemical and geomechanical characteristics of the Opalinus Clay. It also includes experiments for investigating the interaction between the engineered barriers and the host rock.

## **DECOMMISSIONING AND DISMANTLING POLICIES AND PROJECTS**

### **CURRENT status**

To date, the research reactors DIORIT and SAPHIR at PSI, the research reactor at the University of Geneva and the experimental reactor at Lucens have been decommissioned or are in the process of being decommissioned. No commercial power reactors have been shut down or decommissioned.

## **RADIOACTIVE waste management for D&D**

If, at the time of arising of decommissioning waste, the L/ILW repository is not yet in operation, the waste can be stored at the centralised interim storage facility, where sufficient space is available for the decommissioning waste from the older NPPs. However, it is expected that the majority of decommissioning waste will be directly disposed of in an underground repository.

## **FUNDING for D&D**

The fund for financing the decommissioning and dismantling of nuclear installations (see under “Financing” below) no longer in service was set up more than 20 years ago to cover costs arising from the decommissioning and dismantling of nuclear installations no longer in use and from the management of the waste produced. Such a fund, into which the owners have to make advance payments, is required by the Nuclear Energy Act. The fund is administered by the Federal Government.

## **TRANSPORT**

All shipments of radioactive waste have to comply with Swiss nuclear energy and radiation protection legislation as well as with national and international transport regulations and recommendations. Switzerland has integrated the International Atomic Energy Agency's transport recommendations into its national regulations. ENSI is responsible for safety and control aspects of the shipment of radioactive materials.

The five Swiss NPPs, the PSI research institute and various hospitals, industrial facilities and research institutes are producers and users of radioactive materials. Shipments are carried out by several companies which specialise in the transport of radioactive materials.

## **COMPETENT AUTHORITIES & RESPONSIBILITIES**

The federal government is responsible for providing the legal framework, and its supervisory authorities are responsible for the supervision of NPPs and the disposal of radioactive waste. The producers of radioactive waste are required to provide a safe means of its disposal and to bear the associated costs. For this purpose they established the National Co-operative for the Disposal of Radioactive Waste (Nagra).

The Government is currently advised on radioactive waste management issues by:

- the Federal Nuclear Safety Inspectorate (ENSI, formerly HSK, see below)
- the Federal Commission on Nuclear Safety (KNS, formerly KSA, see below),
- the Commission for Nuclear Waste Disposal (KNE), which is mainly concerned with geological issues, and
- the Federal Interagency Working Group on Nuclear Waste Management (AGNEB).

SFOE participates in the organisation and implementation of the various licensing procedures,

and prepares decision-making bases for the responsible federal department and the Federal Council. It supervises operation of nuclear facilities and transportation. Licences and permits required for the construction of nuclear facilities and deep geological repositories, as well as for carrying out geological studies, are issued by the Federal Government.

The Swiss Federal Office of Public Health (FOPH), which is answerable to the Swiss Federal Department of Home Affairs (FDHA), is responsible for waste produced from the healthcare sector, industry and research. It regulates the radiological protection (except in nuclear facilities). It is also responsible for measuring levels of radioactivity in the environment.

The Nuclear Energy Act requires the supervisory body for nuclear facilities (formerly HSK) to be separated from the licensing authority (SFOE). In accordance with this requirement, a new law was passed and, in January 2009, HSK became an independent organisation called ENSI (Eidgenössisches Nuklear-Sicherheitsinspektorat or Swiss Federal Nuclear Safety Inspectorate). Together with the transition from HSK to ENSI, the former Federal Commission for the Safety of Nuclear Installations (KSA) was replaced as of January 2008 by a smaller, more streamlined Commission on Nuclear Safety (KNS).

According to Swiss law, the producers of radioactive waste are responsible for its safe management. In 1972, the electricity supply utilities that operate the NPPs and the Federal Government, which is responsible for the radioactive waste arising from medicine, industry and research, therefore set up the *National Cooperative for the Disposal of Radioactive Waste (Nagra)*. Nagra is responsible for all preparatory work for the disposal of all categories of waste. The owners of the NPPs have also set up the company *Zwischenlager Würenlingen AG (ZWILAG)*, which is responsible for operating the ZWILAG centralised interim storage facility for vitrified waste, spent fuel and other wastes, as well as the on-site conditioning facilities, including the plasma incinerator. Responsibility for spent fuel reprocessing and transport, waste conditioning and on-site interim storage at the NPPs remains with the utilities.

## FINANCING

Under Swiss law, the producers of radioactive waste are required to cover the costs of managing their wastes. Since the beginning of nuclear energy production, these costs have been provided for by setting aside financial reserves debited to the annual accounts during the operating lifetime of the power plants. These costs are an integral part of the operating costs and energy production costs. Current expenditure arising while the NPPs are still in operation, including the costs of conditioning operational waste at the power plants, reprocessing of spent fuel, operating centralised waste treatment facilities, research carried out by Nagra and constructing interim storage facilities, are covered directly by the producers on an annual basis. The costs for decommissioning nuclear facilities and for waste management, including disposal, in the period after shutdown of the individual NPPs are covered by two separate funds, in accordance with the nuclear energy legislation. These funds are administered by a commission nominated by the *Federal Government*.

The *Decommissioning Fund* was set up in 1984 to cover the costs of decommissioning and dismantling, as well as the conditioning, transport and disposal of decommissioning waste. Annual contributions from the NPPs are calculated on the basis of an assumed NPP operating lifetime of 50 years (except for the Mühleberg NPP, for which a lifetime of 40 years is assumed). The ZWILAG interim storage facility also contributes to this fund. As of the end of 2008, the fund contained 1,069 million Swiss francs (approx. 705 million euros).

The *Waste Disposal Fund* for NPPs was set up in 2000. It must cover the costs of all activities associated with management of operational waste and spent fuel elements after the end of the operating lifetime of the power plants. These activities include packaging, transport, conditioning of spent fuel elements for direct disposal, interim storage and the construction, operation and closure of repositories. Annual contributions are based on estimates of waste management costs, which are subject to periodic review. At the end of 2008, the fund contained 2,308 million Swiss francs (approx. 1 523 million euros).

## **PUBLIC INFORMATION**

In Switzerland, a wide range of information is available to the public. SFOE issues media releases, organises media conferences, posts information on its website ([www.radioactivewaste.ch](http://www.radioactivewaste.ch)) and publishes brochures for the general public on specific issues. It releases every year a report encompassing a review of the past year. ENSI publishes brochures on special topics and provides independent public information on safety issues. Nagra publishes technical reports (Nagra Technical Report (NTB) series), as well as brochures on specific topics of interest; a periodical information brochure is also available. Comprehensive information is also available on the Nagra website ([www.nagra.ch](http://www.nagra.ch)). For Nagra, it is also of great importance to engage in dialogue with all involved organisations and with regional population groups. The overall aim is to be available at all times as a reliable source of information and as a dialogue partner. Apart from events organised by Nagra itself, Nagra staff also attend events organised by opponent groups as observers and make themselves available, if required, for open discussion. For more information, the websites of relevant organisations are listed below.

## **WEBSITES**

### **GOVERNMENT**

#### **Swiss Federal Office of Energy (SFOE)**

Bern

Website: <http://www.radioactivewaste.ch>

E-mail: [sachplan@bfe.admin.ch](mailto:sachplan@bfe.admin.ch)

#### **Swiss Federal Nuclear Safety Inspectorate (ENSI)**

Villigen

Website: <http://www.ensi.ch>

E-mail: [info@ensi.ch](mailto:info@ensi.ch)

### **RESEARCH**

#### **Paul Scherrer Institute (PSI)**

Villigen

Website: <http://www.psi.ch>

E-mail: [pubrel@psi.ch](mailto:pubrel@psi.ch)

#### **National Cooperative for the Disposal of Radioactive Waste (Nagra)**

Wettingen

Website: <http://www.nagra.ch>

E-mail: [info@nagra.ch](mailto:info@nagra.ch)

#### **Grimsel Test Site**

Website: <http://www.grimsel.com>

#### **Mont Terri Rock Laboratory**

Website: <http://www.mont-terri.ch>

### **INDUSTRY**

#### **National Cooperative for the Disposal of Radioactive Waste (Nagra)**

(see above)

#### **ZWILAG Zwischenlager Würenlingen AG**

Würenlingen

Website: <http://www.zwilag.ch>

E-mail: [info@zwilag.ch](mailto:info@zwilag.ch)