RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING IN FINLAND

1. NATIONAL FRAMEWORK FOR MANAGEMENT AND REGULATION OF RADIOACTIVE WASTE AND DECOMMISSIONING

1.1 National framework

1.1.1 Overview of national policy

Nuclear waste, regulated by the nuclear energy legislation, is defined as radioactive waste in form of spent fuel or in some other form, generated in connection with or as a result of the use of nuclear energy.

Construction of a major nuclear waste facility shall be in line with the overall good of the society, as judged by the Government and the Parliament. Consent of the proposed host municipality is required for the construction of such facility. An Environmental Impact Assessment shall be conducted prior to the first authorization step of a major nuclear waste facility.

Licensee of a nuclear waste facility shall ensure its safe use, including nuclear safety, safeguards, security and emergency preparedness. Safety of nuclear waste facilities shall be kept as high as reasonably achievable and all actions justified by safety research and the progress in science and technology, shall be taken to enhance safety.

Producer of nuclear waste is responsible for the waste management and decommissioning, including related planning, research and development work, and is also responsible for financing the costs of future management of his waste and of decommissioning of his facility. The State is responsible for nuclear waste after its approved disposal and has the secondary responsibility in case that a producer of nuclear waste is incapable to fulfil his management obligation.

The Nuclear Energy Act states that nuclear waste generated in Finland shall be handled, stored and permanently disposed of in Finland (exemption for e.g. research reactor spent fuel). Respectively, nuclear waste generated elsewhere than in Finland, shall not be handled, stored or permanently disposed of in Finland. The Ministry of Employment and the Economy (MEE) has issued a long-term schedule for the implementation of nuclear waste management.

Facilitation of decommissioning shall be considered already in the design of a nuclear facility. Decommissioning plans shall be updated regularly during the operation of the facility. Implementation of decommissioning shall not be unjustifiably postponed.

Other radioactive waste than nuclear waste, including NORM waste, is subject to the Radiation Act. Each user of radioactive substances is required to take all the measures needed to render harmless the radioactive waste arising from his operations. The state has the secondary responsibility in case that a producer of radioactive waste is not capable to fulfil his management obligation.

The Radiation Act provides for furnishing a financial security for radioactive waste with substantial liability. The options for disused sealed sources are either return to the supplier/manufacturer or delivery to the Radiation and Nuclear Safety Authority (STUK) against a waste management fee.

Finland has ratified the London Convention and the Joint Convention.

1.1.2 Overview of relevant institutions

According to the Nuclear Energy Act, MEE shall decide the principles on the basis of which the nuclear waste management is to be implemented. Prior to the decision, MEE shall consult the pertinent organisations, particularly the nuclear waste producers, STUK and the Ministry of Environment.

Key organisations for the implementation of radioactive waste management are:

- The NPP utilities Fortum Power and Heat (FPH) and Teollisuuden Voima (TVO) take care of interim storage of spent fuel, conditioning and disposal of LILW and of planning for the decommissioning of NPPs
- The NPP utility Fennovoima (FV) continues planning on the future implementation of radioactive waste management
- A joint company by FPH and TVO, Posiva, is responsible for the preparations for and later implementation of spent fuel disposal
- VTT takes care of the management of nuclear waste from the small 250 kW Triga research reactor it operates
- STUK operates a central interim storage for small user radioactive waste.

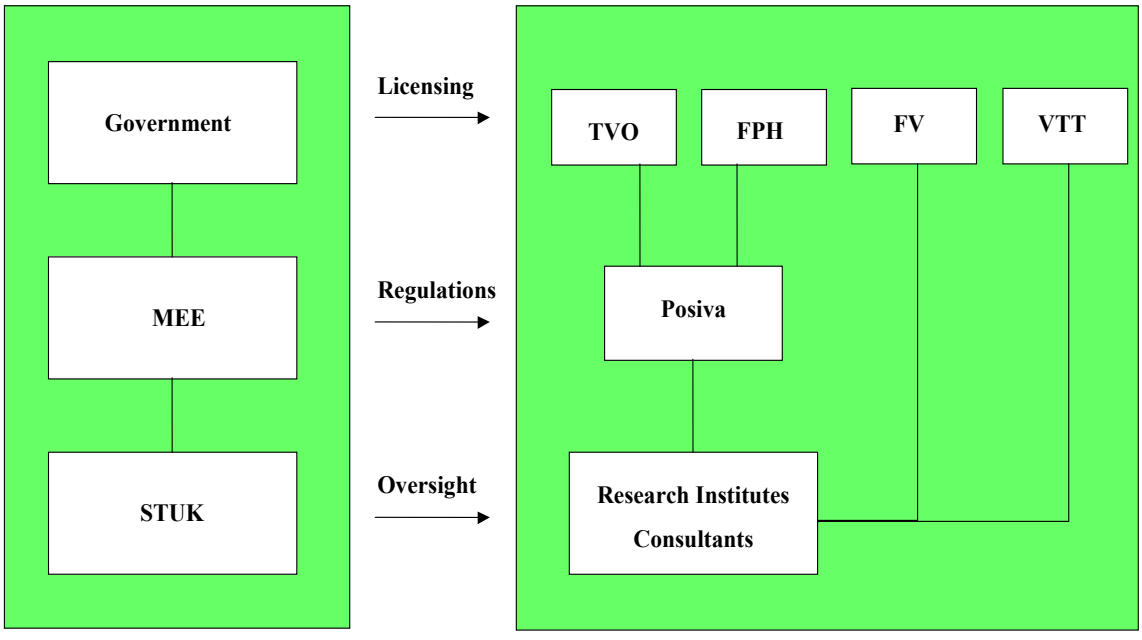
1.2 National technical regulatory organisations

1.2.1 Regulatory functions

The key organisations for regulatory functions are:

- The Government grants licenses for nuclear facilities and issues general safety regulations
- MEE oversees that waste management and related R&D complies with the national policy and, together with the State Nuclear Waste Management Fund, that provisions for future waste management are adequate
- STUK is responsible for the regulatory oversight of radiation and nuclear safety, for issuing detailed safety regulations and for the technical and safety related review of licence applications and other important documents.

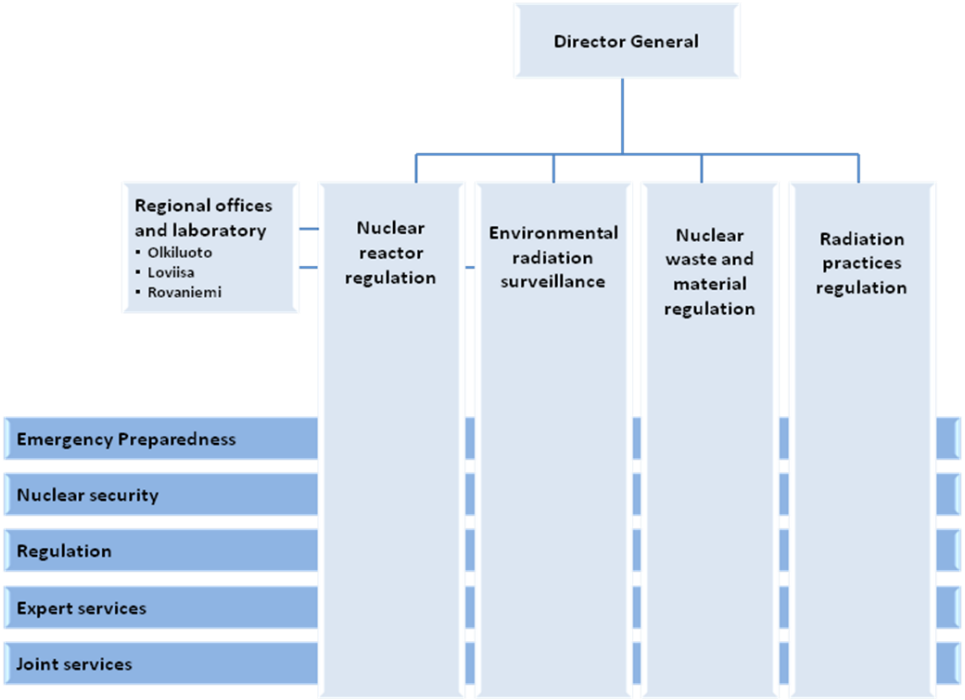
Figure 1. **Main bodies involved with nuclear waste management**



1.2.2 Organisations and resources

The number of full-time waste management professionals is one at the MEE and 17 at STUK. Whenever required, the expertise of STUK's other units or external expert groups are employed for the review of important waste management documents. STUK has an Advisory Commission on Nuclear Safety.

Figure 2. **STUK's organisational chart**



1.3. National implementing organisations

1.3.1 Scope of responsibility

The implementing organisations and their responsibilities regarding nuclear and radioactive waste management are discussed in chapter 1.1.2.

1.3.2 Organisation and resources

The most important implementing organisation is Posiva which has close to one hundred employees. Posiva and the NPP utilities employ a number of experts in domestic and foreign research and consultancy organizations via research and development commissions.

2. LEGAL FRAMEWORK

2.1 Primary legislation and general regulations

The main laws and ordinances regulating waste management activities are (see:www.stuk.fi/en_GB/):

- Nuclear Energy Act (1987) and Decree (1988) define the responsibilities, licensing and enforcement procedures and the financing system for future nuclear waste management
- Decree on the State Nuclear Waste Management Fund (1988) specifies the system for financing future nuclear waste management
- Radiation Act and Decree (1991) include e.g. general radiation protection principles, provisions for radiation work and provisions for management of non-nuclear radioactive waste
- Environmental Impact Assessment Act (1994) defines the EIA process to be implemented prior to the first licensing step pursuant to nuclear energy legislation
- Act and Decree on Radiation and Nuclear safety Authority define STUK's regulatory rights and responsibilities (1991).

2.2 Regulations concerning specific activities and facilities

2.2.1 Radioactive waste management

The following general safety regulations, issued by the Government, relate to nuclear waste management (see:www.stuk.fi/en_GB/):

- Government Decree on the safety of nuclear power plants (2008) addresses also interim storage of spent fuel and treatment and conditioning of operational LILW at NPPs.
- Government Decree on the safety of a disposal of nuclear waste (2008) addresses disposal of all kind of nuclear waste.

2.2.2 Decommissioning

The Nuclear Energy Act and Government Decree on the safety of nuclear power plants include some general provisions for decommissioning.

2.3 Guidance on implementation

2.3.1 Radioactive waste management

The detailed safety regulations are given as STUK-guides. The licensee shall comply with these guides unless he puts forward some other acceptable procedure or solution, by which a comparable safety level is achieved. The YVL guide group D is related to nuclear or other radioactive waste management (see: www.stuk.fi/en_GB/):

- Guide YVL D.2 Transport of nuclear materials and nuclear waste
- Guide YVL D.3 Handling and storage of nuclear fuel
- Guide YVL D.4 Predisposal management of low and intermediate level nuclear waste and decommissioning of a nuclear facility
- Guide YVL D.5 Disposal of nuclear waste

In the preparation of the technical rules, international conventions, standards and recommendations (IAEA, WENRA) are utilised, whenever applicable.

The new YVL Guides entered into force in December 2013.

2.3.2 Decommissioning

Decommissioning is addressed in the Guide YVL D.4.

2.4 Licensing procedures

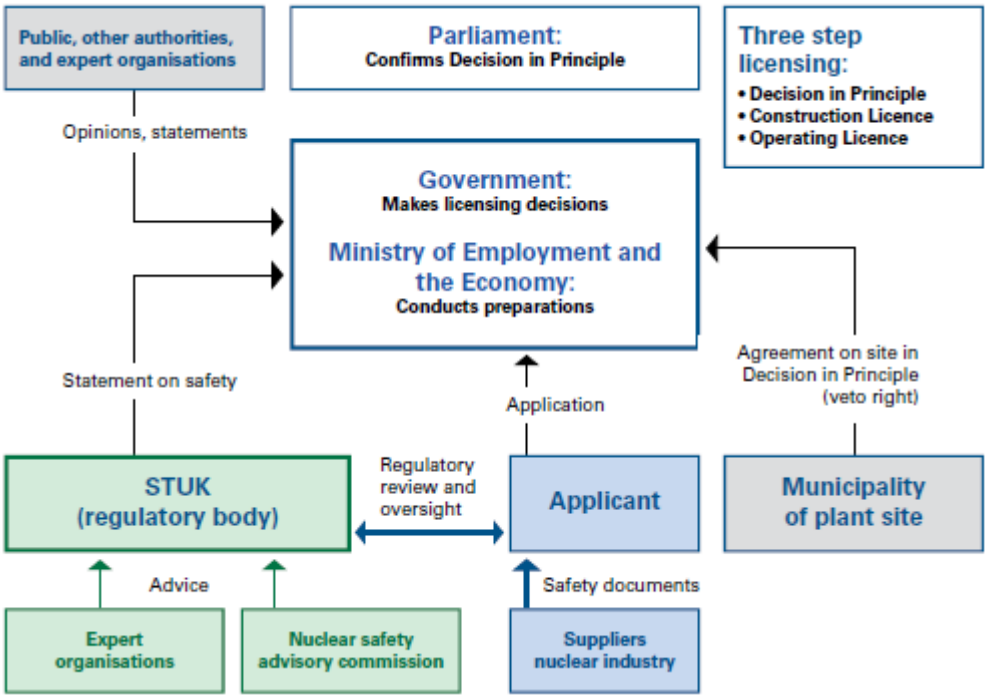
For major nuclear facilities, including spent fuel storages and disposal facilities, the nuclear legislation defines a three-step authorization process:

- Decision-in-principle; the Government makes the licensing decision, prior approval by the host municipality and ratification by the Parliament are required.
- Construction license, issued by the Government.
- Operating license, issued by the Government.

STUK conducts the safety review in each of these licensing processes and MEE prepares the authorization decisions.

For other nuclear facilities, only construction and operating licenses granted by the Government are required. Minor licenses for nuclear waste management operations and for management of non-nuclear radioactive waste are granted by STUK.

Figure. 3. **Authorization of nuclear facilities**



3. WASTE MANAGEMENT STRATEGY AND CURRENT PRACTICE

3.1 Waste classification and quantities

The sources of nuclear wastes are the two NPPs with four reactors together (Loviisa 1&2 and Olkiluoto 1&2) and a small research reactor. Other radioactive wastes arise from a number of facilities using radioisotopes in medical, research and industrial applications.

The amounts of stored or disposed radioactive wastes at the end of 2013 were as follows:

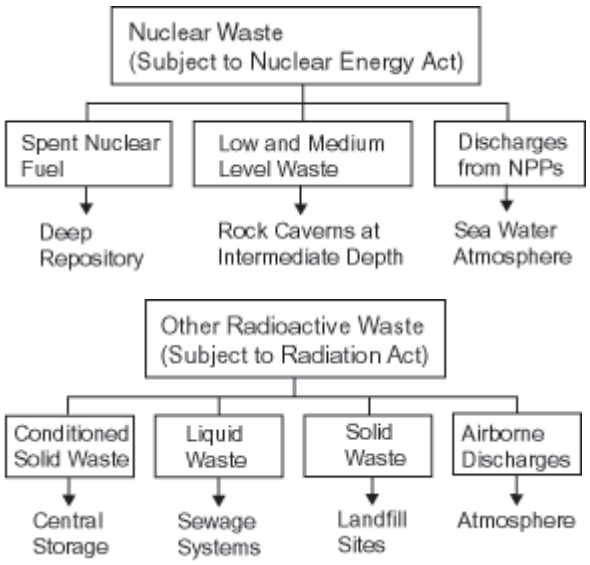
- Spent nuclear fuel: 12 753 assemblies(about 1984 tHM, mostly uranium)
- LILW from NPPs: about 9556 m^3, of which about 7567 m^3 has been disposed of
- Small user radioactive waste in central storage: about 56 m^3

Decommissioning of the NPPs currently in operation is estimated to generate 56 500 m^3 of LILW.

Waste categorization according to their disposal route is illustrated in Figure 3. Classification of wastes is defined in the following documents:

- For the purpose clearance, Guide YVL D.4 defines activity concentration levels below which the nuclear waste is not regarded as radioactive. For small user waste, exemption levels for disposal in landfill or sewage system are defined Guide ST 6.2.
- For the purpose on processing and storage, Guide YVL D.4 defines the activity concentration levels for low-level, intermediate-level and high-level waste
- For the purpose of disposal, Government Decree 736/2008 defines short-lived and long-lived waste and Guide YVL D.5 defines the requirements for the final disposal facilities

Figure 4. **Categorization of radioactive residues for disposal purpose**



3.2 Waste management strategy

According to the nuclear energy legislation, nuclear waste shall be permanently disposed of in Finland. An exception is the spent nuclear fuel from the research reactor at VTT, which is of U.S. origin and can be returned to U.S.A. according to the U.S.DOE spent nuclear fuel acceptance programme. A spent fuel disposal programme is being implemented by Posiva with the following main objectives, which are in line with MEE's decision:

- Disposal site selection in 2000 (the Olkiluoto site was proposed by Posiva in the decision-in-principle application of 1999; the application was approved by the host municipality in Jan 2000, the decision was made the Government in Dec 2000 and ratified by the Parliament in May 2001)
- Start of construction of an underground rock characterisation facility at Olkiluoto in 2004, the repository depth of 420 m was reached in 2010
- Construction licence application for the disposal facility in December 2012
- Start of operation of the disposal facility around 2020.

FPH and TVO have on-site pool-type interim storages for spent fuel. At the Loviisa NPP, the current storage capacity is adequate until the start of disposal. The capacity of the Olkiluoto interim storage will be expanded by the year 2014.

FPH and TVO have rock cavern-type repositories for operational LILW at their NPP sites. The repository at the Loviisa site became operational in 1998 and that at the Olkiluoto site in 1992. Both utilities plan to dispose of also decommissioning wastes into extensions of these repositories.

Fennovoima has indicated that it intends to construct a rock cavern-type repository for operational LILW at its NPP site and also considers a surface based facility as an option for the disposal of very low level waste. Fennovoima continues carrying out studies on developing a joint repository with current Finnish NPP licence holders as well as studies on its own repository for spent fuel.

The preferred strategy for disused sealed sources is the return to their manufacturers. Such sources and small-user waste that cannot be cleared from regulatory control can be transferred to STUK upon compensation, which covers the storage and disposal costs. STUK operates a rock cavern interim storage located in the premises of the Olkiluoto LILW repository.

3.3 Waste management issues at national level

The greatest challenges relate to the programme for the disposal of spent fuel in the bedrock of the Olkiluoto site, for which the construction licence application was submitted in 2012. An extensive research, development and design programme is underway to resolve the remaining open issues related to the licensing of the repository. STUK has regulated the spent fuel disposal project i.a. by reviewing triennial programme reports and important safety reports and by overseeing the activities in the underground rock characterisation facility, which is envisaged to constitute a part of the future spent fuel disposal facility.

The European Directive on the Management of Spent Fuel and Radioactive Waste calls for national programmes for the management of all kind of radioactive waste. One issue is establishing the final management of disused sealed sources that cannot be returned to the supplier/manufacturer or for which other acceptable destination cannot be found by the owner. Such sources and other small-user waste are received for interim storage in a rock cavern in Olkiluoto, and can be disposed of in the Olkiluoto LILW repository. However, the current capacity and activity inventory limits of the reporsitory cannot accommodate the disposal of few of the largest sealed sources. These will be stored in the interim storage, and disposal options are being investigated.

Another issue is the decommissioning waste from the FiR 1 research reactor that will require interim storage and a final disposal option. VTT is currently negotiating with the nuclear power companies about the possibilities to use their interim storage and forthcoming final decommissioning waste repositories. The latter ones are not yet licensed, and therefore long interim storage is required in any case with the current research reactor decommissioning strategy. A special technical issue is the aluminium and graphite waste of the research reactor, which will require additional studies.

3.4 Research and development

3.4.1 Research infrastructure

Producers of nuclear waste are obliged to carry out R&D for the safe management of their wastes. The program is focused on spent fuel disposal and carried out by Posiva. Posiva's budget for 2014 is about 70 million euros, half of which can be attributed directly to research and technology development. Extensive geological investigations as well as development of disposal technology and performance assessment methodology have been carried out over 20 years. At-depth investigations in the Olkiluoto rock characterization facility are ongoing. Every three years, a comprehensive report on the results from and the further plans for the utilities' research, development and technical design programme is submitted for regulatory review.

There is also a Public Sector's Research Programme (KYT-programme) aimed at supporting the regulatory activities and maintaining expertise in the field. Its volume is about 1.9 million euro per year and the programme is financed from a fund augmented by the licensees. The main organisations participating in the Public Sector's Research Programme are Technical Research Centre of Finland, Geological Survey of Finland, Radiochemical Laboratory of Helsinki University and Aalto University School of Science and Technology. The programme is steered by a group consisting of representatives from the authorities, Posiva and the utilities.

The representatives of the Finnish research institutes, authorities and utilities participate in the waste management related co-operation within the European Union, OECD/NEA and IAEA. Finnish researchers, supported financially by Posiva, participate in the nuclear waste management related integrated research projects of the European Commission. Posiva has extensive collaboration with the Swedish SKB and also formal bilateral co-operation agreements with ANDRA (France), DBE (Germany), NAGRA (Switzerland), JAEA, NUMO and RWMC (Japan) and NWMO (Canada).

In the absence of internal regulatory research staff, STUK relies on external domestic or foreign experts to obtain adequate support for its regulatory activities. STUK's regulatory support activities are charged directly from the utilities (volume several hundred thousand euros per year).

3.4.2 Contents of R&D plans

Posiva's R&D programme is focussed on resolving the open issues related to spent fuel disposal. Areas of particular interest include (see also www.posiva.fi/en/databank/publications/other_publications):

- At-depth site characterization: site suitability classification, design of the disposal facility and obtaining geological data for the safety case
- Development of disposal technology: disposal canister fabrication and sealing, buffer and backfill emplacement, studies of the alternative horizontal deposition concept
- Engineered barrier performance confirmation: studies of canister performance and, buffer and backfill behaviour in the resaturation phase and in the long-term
- Safety case development: site specific modelling, uncertainty assessment.

Studies in the Public Sector's Research Programme are focussed on specific issues related to spent fuel disposal. More information can be found via http://kyt2014.vtt.fi. STUK's regulatory support activities aim at deepening the reviews of the reports submitted by Posiva (external review teams), developing STUK's independent assessment capabilities and resolving key issues related to the safety of nuclear waste disposal.

3.5 Financing of radioactive waste management

3.5.1 Framework and responsibilities

The basic goals of the financing system is to ensure that waste management and decommissioning costs are included in the price of nuclear electricity and to ensure that assets are available even in case of insolvency of the waste generator. The features of the system are the following:

- It covers all spent fuel and nuclear wastes management and decommissioning activities, including R&D
- Costs estimates based on remaining management costs of existing waste amounts, current price level with no discounting and on the use of currently available technology
- The whole liability has to be covered, either by funded money or by securities
- Utilities (and operator of the research reactor) pay annually fees to cover their liability (or get paybacks if the liability decreases)
- A segregated fund, the State Nuclear Waste Management Fund, exists under the administration of the MEE for collecting, holding and investing the assets.

3.5.2 Status of financing schemes

The funding system works so that the licence-holders submit every three years to MEE a waste management scheme with related cost calculations and liability assessments. The Ministry requests statements from STUK and from an organisation having competence in technological cost assessments. The licence-holders have an opportunity to respond to the statements. Thereafter, the Ministry confirms the liabilities and fund targets, and the licence-holders pay contributions to the Fund (or obtain returns) and provide the required securities to the State. The process takes about half year.

At the end of 2012, the total undiscounted liability was around 2 300 million euro and the funded money amounted to about 2 270 million euro. The liability covers the costs of the future management of spent fuel and radioactive waste generated so far and of the decommissioning of the NPPs. The nuclear waste management liability adds about 10 % to the production costs of nuclear electricity.

4. DECOMMISSIONING STRATEGY AND CURRENT PRACTICE

4.1 Decommissioning strategy

The utilities must update the decommissioning plans of NPPs for regulatory review every six years (latest updates were submitted in 2008 for Olkiluoto NPP and in 2012 for Loviisa NPP).

The decommissioning plan for the Loviisa NPP is based on immediate dismantling after shutdown. The actual dismantling work takes about 11 years. This strategy is justified by the feasibility of decommissioning of the primary circuits and by the need of the site for new electricity generation capacity.

The decommissioning plan for the Olkiluoto 1 and 2 is based on safe storage for 30 years prior to dismantling. This strategy is justified by the difficulty of decontamination of the contaminated circuits. Also, the continuation of nuclear activities at the site is foreseen towards the next of century making competent workforce available for the decommissioning projects. The tentative decommissioning plan for the Olkiluoto 3 unit is based on immediate dismantling.

According to the plans, wastes from the decommissioning of the reactors will be disposed of in underground repositories co-located with those for operational LILW at the power plant sites. Large components like pressure vessels and generators are planned to be removed and disposed of intact i.e. without cutting them in pieces. Engineered barriers will be selected taking into account the level and longevity of radioactivity in each waste type.

4.2 Status of decommissioning projects

No decommissioning and dismantling works of nuclear facilities are underway. Preparations for the decommissioning of the 250 kW FiR 1 Triga Mark II at VTT have started. VTT submitted in November 2013 an Environmental Impact Assessment (EIA) programme to the coordinating authority, MEE. MEE requested statements on the assessment programme from 22 authorities and three nuclear companies. The programme was also open for public opinion in a public hearing and on the website of MEE. The statement by coordinating authority was issued in February 2014. The EIA report is planned to be completed during 2014.

4.3 Decommissioning issues at national level

The authorization system for decommissioning is included in the amendment of the nuclear energy legislation which entered into force in 2008. A safety guide for decommissioning became effective in 2013. Development of the decommissioning technology will be followed and the decommissioning plans and safety evaluations will be updated if substantiated by these developments.

4.4 Research and development

Research and development related to decommissioning is mainly conducted by the utilities FPH and TVO. It aims at supporting the next updates of the decommissioning plans, to be submitted by the end of 2014. The studies address e.g.

- Measurements for updating the activity inventory in decommissioning waste
- Long-term corrosion of steel components and long-term durability of concrete structures in repository conditions
- Further development of safety assessment methodology for the disposal of decommissioning waste
- Technical options for decommissioning
- Decommissioning cost updating.

4.5 Financing of decommissioning

Financing of the future decommissioning costs is including in the financing system for radioactive waste management described in chapter 3.5.

ACRONYMS AND ABBREVIATIONS

MEE Ministry of Employment and the Economy
STUK Radiation and Nuclear Safety Authority
FV Fennovoima Oy
FPH Fortum Power and Heat Oy
TVO Teollisuuden Voima Oyj
VTT Technical Research Centre of Finland
NPP Nuclear power plant
LILW Low and intermediate level waste