REPUBLIC OF ESTONIA

MINISTRY OF THE ENVIRONMENT

NATIONAL PROGRAMME FOR RADIOACTIVE WASTE MANAGEMENT

TALLINN 2015

ANNOTATION

Preparation of the national programme for radioactive waste management

The need to prepare the national programme (hereinafter programme) for radioactive waste management arises from the National Radiation Safety Development Plan for 2008–2017 approved in 2008 (hereinafter *NRSDP*) and its implementation plan. The NRSDP describes the reduction of the threats related to radioactive waste and its management as one of the most important sub-objectives. An overview of the generation of radioactive waste, problems related to it and possible solutions of management, including storage, have been presented in more detail in the NRSDP Safe and coordinated management of radioactive waste is the most important activity for Estonia from the position of ensuring radiation safety, therefore, the compilers of the development plan found that a separate radioactive waste management programme must be prepared. After the approval of the *NRSDP*, the preparation of the programme was launched. To this end, a row of preliminary studies were ordered, among other things, the structure of the programme was prepared, the methodology for assessing the radioactive waste stream and electronic data was developed. Additionally, a study of the management options of materials containing natural radionuclides and materials contaminated with them was completed. Both the *NRSDP* as well as the specified documents served as a good basis for preparing the programme. Council Directive 2011/70/EURATOM establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste came into force in 2011 (hereinafter *Directive 2011/70/EURATOM*), which establishes even more precise requirements for the preparation of a national programme for radioactive waste management. In 2013, the European Commission also prepared guidelines for Member States for the preparation of the programme specified in the directive in order to ensure a uniform structure of the plan and the extent of topics covered. Therefore, the draft of the programme was also updated according to the requirements of the directive and guidelines.

Matters related to radioactive waste management will be organised more precisely on the basis of the programme and the aim of the plan is to offer decision-makers and waste handlers specific solutions for the systematic management of radioactive waste and to reduce their amounts in the Republic of Estonia. The plan also offers enough information for the wider public about the radioactive waste generated and to be generated, as well as their management.

The structure of the programme is as follows:

1) National policy;
2) Milestones and timeframes;
3) Inventory;
4) Concepts or plans and technical solutions from generation to disposal;
5) Concepts, plans for the post-closure phase;
6) Research,development & demonstration activities;
7) Responsibilities, performance indicators;
8) Cost assessment;
9) Financing scheme;
10) Transparency policy or process;

11) Agreements;

12) Lead document.

The programme presents the sub-objectives of the described elements, measures and expected results until 2050. The responsible institutions and the costs of the programme are also described.

The national programme for radioactive waste management is a source document, which in addition to the above gives an overview of the legislation in force and directions for supplementing them. The existing institutional organisation, financial means and their need in the future have been indicated in the programme. As the management of radioactive waste is of interest to different interest groups (both domestically as well as internationally), the programme is a good tool for communicating with them, for example, distributing information to the interest groups and introducing the current situation and future plans. As the interest groups were involved in the preparation of the programme, the document is a certain agreement, which promotes the future development of the field.

The programme is regularly reviewed and updated, taking into account the achievements of technology and research, as well as recommendations by experts, best experiences, and good practice. According to Directive 2011/70/EURATOM, the national framework, competent regulatory body, national programme and its application are assessed regularly and at least once in ten years for achieving a high level of the safety norms of the safe management of spent fuel and radioactive waste, and the help of international experts is used for it. The results of expert assessments will be communicated to the European Commission and other Member States and these are made available to the public without breaching the fundamental principles of law.

The coordinators for preparing the programme included Head of the Climate and Radiation Department of the Ministry of the Environment Evelyn Müürsepp and Senior Officer Krista Saarik. Head of A.L.A.R.A. AS Joel Valge and Environmental Technology Adviser Ivo Tatrik, Head of the Radiation Department of the Environmental Board Ilmar Puskar, Head of the Radiation Protection Bureau Karin Muru and Head of the Radiation Monitoring Bureau Monika Lepasson, and Head of QPRE OÜ and qualified radiation expert Merle Lust participated in the work as experts. The plan has been coordinated with the Ministry of the Interior, the Ministry of Economic Affairs and Communications, and the Ministry of Finance. The Minister of the Environment will approve the programme with an order. The programme is coordinated with the European Commission.

After the completion of the programme, a relevant press release will be published and a free information seminar will be organised. A summary of the programme will also be uploaded on the website of the Ministry of the Environment.

The coordinators of the work would like to thank everyone who participated in the preparation of the programme for their contribution to the completion of the document.

Contents

1. Introduction

Substances, materials or items that contain radionuclides or have been contaminated with them, have greater activity or specific activity than the clearance levels established on the basis of the Radiation Act, and are not planned to be used in the future, are considered radioactive waste. Radioactive waste is generated as a result of various activities, the activity and volume of the radioactive waste generated also varies to a great extent. The radioactive waste generated may be in solid, liquid or gaseous form. Radioactive waste can be divided into very low-, low-, intermediate-, and high-level waste on the basis of activity. Waste existing and generated in Estonia is primarily very low-, low- and intermediate-level solid waste. Liquid radioactive waste is generated to a small extent.

There are no nuclear power plants in Estonia and there are also no activities related to and facilities operating with nuclear fuel cycle. Since Paldiski former nuclear site is a training centre, which does not directly fall within the scope of Directives 2009/71/EURATOM and 2014/87/EURATOM, Estonia must implement the requirements of these Directives on a general level. As ensuring safety is very important for Estonia, the requirements of the Directives will be considered to the maximum extent possible when decommissioning the Paldiski site, and simultaneously ensuring a reasonable administrative burden.

Most of the radioactive waste in Estonia originates from the Soviet Union time. Nowadays, the main generators of radioactive waste are medical, industrial, and research establishments that hold a radiation practice licence.

The generation of a considerable amount of NORM waste can also be considered a specificity of Estonia. Currently, the Radiation Act only establishes the term of NORM waste, which in itself refers to the fact that its management is not possible. Some types of NORM waste can be mixed, dispersed and cleared, thereby reducing the environmental pressures and resource costs. Therefore, the judicial area must be organised first, which would allow for NORM waste to be used as secondary raw material. The management of such residues and waste also requires a case-by-case approach, as depending on the origin, they have different chemical and physical characteristics and they cannot be managed together with other radioactive waste.

It can be said in summary that the waste streams in Estonia are small and the selection of suitable management methods is relatively restricted. Estonia does not have many options for reducing the volume of the waste generated, because all existing technologies (for example, waste incineration) are very expensive, with a powerful management volume, and the investment into the waste management technologies is likely to be significantly greater than constructing a ground-level final disposal site. If possible, however, alternatives must also be found, for example, the processing, dispersion or clearance of waste. These alternatives were also analysed in the course of preparing the programme.

The preparation of a national programme for radioactive waste management is required by the National Radiation Safety Development Plan for 2008–2017 approved by the Government of the Republic in 2008, as well as by Directive 2011/70/EURATOM. The programme gives an overview of the radioactive waste currently existing and to be generated in Estonia in the future and its management ways, establishes a time schedule for the activities and national policy. Bodies authorised for the safe management of radioactive waste, existing technical and financial means, financing scheme and research and development activities are also described in the plan. The national planning of radioactive waste takes place through the programme.

It is presumed that the national programme for radioactive waste management will help to increase public awareness. Interested parties will better understand the problems related to the management of radioactive waste and thanks to that, the awareness of the population may improve and through it, also confidence in this field.

2. International and national obligations

More general and specific principles of the management of radioactive waste have been regulated both at an international level as well as in legislation established in the Republic of Estonia. Also, the Republic of Estonia joined the International Atomic Energy Agency (hereinafter *IAEA*) in 1992.

2.1. *International conventions and directives*

The Republic of Estonia has joined several international conventions in the field of radiation safety, inter alia, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, and the Convention on Nuclear Safety, which was ratified in 2005.

From the position of radioactive waste management, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, the aim of which is the protection of residents and the environment against radioactive waste generated in the civilian area and dangers arising from the management of spent fuel, is one of the most important conventions. The parties to the convention confirm in the preamble of the convention that the state is responsible for ensuring the safety of the management of spent fuel and radioactive waste in the final stage. The governments must ensure control of the use of radiation sources, including the safe management of orphan sources. To this end, a legal and regulatory system must be created, an independent competent authority (regulative body) must be designated, and the necessary regulations in addition to the Act must be created as well. Aside from the obligations undertaken by joining the convention, participation in the reporting meetings of the convention and the submission of reports are both important.

Legislation of the European Union (hereinafter *EU*) has a very large impact on establishing national requirements. Namely, a Member State must comply with the regulations, directives, and other documents issued at the EU level. In the field of radioactive waste, the legislation we describe in more detail below is more important.

Directive 96/29/EURATOM of the European Council establishing the basic safety norms for protecting the health of workers and the general public against the dangers arising from ionizing radiation. It is a legal act, which regulates matters related to the safety of radioactive waste management. The newer version of this Directive is Directive 2013/59/EURATOM of the European Council, which Member States must enforce by the end of 2018. The new Directive will not bring great changes in the field of radioactive waste management.

Directive 2003/122/EURATOM establishes the control mechanisms of high-level sealed radiation sources and a practice, according to which, on prior agreement, it is possible to return radiation sources to the manufacturer after use, has rooted internationally on its basis. The purpose of the Directive is to prevent exposure of workers and the public to ionising radiation arising from inadequate control of high-activity sealed radioactive sources and orphan sources and to harmonise controls in place in the Member States by defining specific requirements ensuring that each such source is kept under control.

The aim of Directive 2009/71/EURATOM is to create a Community framework, to maintain and promote the continuous improvement of nuclear safety and its regulation, and to ensure that Member States shall provide for appropriate national arrangements for a high level of nuclear safety to protect workers and the general public against the dangers arising from ionizing radiations from nuclear installations.

Directive 2011/70/EURATOM coincides with the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management in content. This Directive establishes a Community framework for the responsible and safe management of spent fuel and radioactive waste. The Estonian programme is largely related specifically to complying with the requirements of this Directive.

2.2. *National regulation*

In the Republic of Estonia, the principles of radioactive waste management and obligations related to management have been established in the Radiation Act. More specific requirements for reducing the volumes of waste generated and ensuring the safe management of radioactive waste are regulated in the regulations issued on the basis of the Act and also in the radiation practice licences issued by the Environmental Board and awarded to the generators and handlers of waste.

The most important regulations of the Government of the Republic of Estonia and the Minister of the Environment are the following:

- Regulation No. 163 of 30 April 2004 of the Government of the Republic “Basis for Deriving the Exemption Levels and Exemption Levels of Radionuclides”. The Regulation establishes the exemption levels by radionuclides, i.e. values of activity and specific activity, and in case these values remain below these levels, it is not necessary to apply for a radiation practice licence. A formula for calculating the exemption level in case of several radionuclides or a mix of radionuclides has been presented in the Regulation as well;
- Regulation No. 193 of 17 May 2004 of the Government of the Republic “Limits of the Effective Dose of an Exposed Worker and Resident and Equivalent Doses of the Lens of the Eye, Skin and Limbs”. The limits of the effective dose and equivalent dose for exposed workers as well as residents are established in the Regulation;
- Regulation No. 243 of 8 July 2004 of the Government of the Republic “Differences of the Procedure for Processing the Documents of the Import, Export and Transit of Radioactive Waste Depending on the Country of Origin and Destination”. The procedure for processing documents for the import, export and transit of radioactive waste is established with the Regulation;
- Regulation No. 244 of 8 July 2004 of the Government of the Republic “The Statutes of Maintaining the National Dose Register of Exposed Workers”. The Regulation establishes the procedure for maintaining the national dose register of exposed workers. The holder of a radiation practice licence must forward the data of doses received by exposed workers to the register;
- Regulation No. 41 of 29 April 2004 of the Minister of the Environment “Terms for the Procedure of Awarding, Amending and Repealing of a Radiation Practice Licence and the Specified Requirements and Forms of the Radiation Practice Licence Application and Radiation Practice Licence Forms”. The Regulation specifies the procedure of the radiation practice licence application process and the list of documents submitted together with the licence application;
- Regulation No. 86 of 8 July 2004 of the Minister of the Environment “Requirements for the Radiation Safety Training of an Exposed Worker”. The Regulation specifies

the requirements for training exposed workers, the content of the training session, and also the frequency of organising the training sessions is determined;

- Regulation No. 93 of 14 July 2004 of the Minister of the Environment "Interference and Acting Levels and the Limit of Emergency Exposure in the Event of Radiation Emergency" establishes the doses for applying protective measures in the event of radiation emergency;
- Regulation No. 113 of 7 September 2004 of the Minister of the Environment "Activity Levels of Radionuclides and Requirements for the Rooms where a Radiation Source is located, for Marking the Rooms and the Radiation Source";
- Regulation No. 8 of 9 February 2005 of the Minister of the Environment "The Classification and the Requirements for the Registration, Management, and Delivery of Radioactive Waste, as well as Compliance Indicators of Radioactive Waste";
- Regulation No. 10 of 15 February 2005 of the Minister of the Environment "Clearance Levels of Radioactive Materials Generated during Radiation Practice or Items Contaminated by Radioactive Material and the Conditions of Their Clearance, Recycling and Reuse";
- Regulation No. 45 of 26 May 2005 of the Minister of the Environment "Procedures for the Monitoring and Assessment of the Effective Doses of an Exposed Worker and Resident and the Values of the Dose Coefficients of Doses Caused by Intake of Radionuclides and of Radiation and Tissue Weighting Factors".

2.3. *National Radiation Safety Development Plan*

The obligation to prepare a National Radiation Safety Development Plan (*NRSDP*) arises from paragraph 7 of the Radiation Act. Its purpose is to ensure an efficient protection of the entire population from the detrimental effect of ionising radiation and the timely notification of the population of radiation danger. The national planning of radiation safety takes place through the *NRSDP*. It is also established that the plan must consider the situation of radiation safety in the country, forecast the development of the field, fix the strategic aims of the development of radiation safety and limits requiring consideration, as well as development principles. The implementation plan accompanying the development plan provides a more precise overview of what is planned in it and persons carrying out the obligations, and also of the necessary expenses. In addition to the safe management of radioactive waste, the *NRSDP* also considers readiness for radiation emergencies, matters related to medical radiation, radioactivity of the environment, and also, for example, increasing public awareness. The preparation and updating of the development plan is coordinated by the Ministry of the Environment of the Republic of Estonia. The first *NRSDP* for the period of 2008–2017 was approved with Regulation No. 182 of the Government of the Republic of Estonia on 17 April 2008. The plan was also accompanied by an implementation plan for 2008–2011. Currently, the implementation plan prepared for 2012–2015 is in force.

3. Policy for managing radioactive waste and spent fuel

The radioactive waste management policy is presented in this chapter. The main aim of the policy is the reduction of waste volumes generated, which ensures that the amount of waste to be managed and stored would be as small as possible. If waste is still generated, it must be managed and stored strategically. The question of liability and the impact of future activity on national policy and the need to involve the public are also considered in this chapter. Estonia does not have a policy of spent fuel management, as there is no nuclear fuel in Estonia. There is, however, the former nuclear submarine training centre together with two reactors in Paldiski, but spent fuel was removed from the reactors and taken back to Russia already in 1995. If a decision is made on taking a new nuclear facility into use in the Republic of Estonia, a policy must also be developed for the management of the waste and spent fuel generated there.

3.1. Decision-making process and responsibility

The Estonian radioactive waste management policy is based on national legislative drafting and international principles. The policy will be implemented through the radioactive waste management programme. The need to prepare a programme is provided in the National Radiation Safety Development Plan approved by the Government of the Republic in 2008 and in the European Union Directive 2011/70/EURATOM on responsible and safe management of spent fuel and radioactive waste.

The shaper of the radiation and nuclear safety policy in Estonia is the Ministry of the Environment. As this policy is of significant importance for the state, other ministries, authorities and the public are also involved in its shaping process. The Minister of the Environment establishes the radioactive waste management programme that directs the policy. The interim storage and final disposal of radioactive waste is organised by the Ministry of Economic Affairs and Communications according to the new Radiation Act expected to be adopted in 2015. Therefore, it is a duty of the state to shape a sectoral policy and establish the necessary legislation and organise the management and interim storage and final disposal of waste.

The generation of radioactive waste is allowed only with a radiation practice licence, therefore, the state controls (in this case, the Environmental Board and the Environmental Inspectorate) in the course of processing the licence application and later inspection as well, whether the waste generator complies with the requirements established by legislation. According to national policy, the generator of the waste is responsible for the management of radioactive waste. If, however, it is historic waste, i.e. waste, which the Republic of Estonia took over with the restoration of independence, or waste the owner of which cannot be ascertained, the state is responsible for its management. If the owner of the waste can be identified later, then the owner must compensate for the state’s expenses. Appropriately processed and packed waste is stored in the state-owned the interim storage of radioactive waste.

3.2. Reduction of waste volumes

According to the Radiation Act, the volumes of generated waste must be kept as low as possible. When planning any radiation activity, the applicant for the licence must prefer technology, which ensures the optimisation of the amount of radioactive waste generated. Nowadays, the main generators of radioactive waste in Estonia include medical, industrial, and research establishments, which own a radiation practice licence. It is ensured through various provisions of the Radiation Act that the amount of radioactive waste generated in the course of any radiation activity would be as small as possible. The applicant for the licence must prove in the course of processing the radiation practice licence application that the main principles of radiation safety are used as the basis for planning the activity. The waste minimisation requirement also applies for sealed radiation sources – when purchasing them, a manufacturer, who agrees to take back the radiation source at least 15 years after the import of the radiation source, must be preferred.

As the amounts of waste generated can be reduced by reusing materials, then if it is possible, this must be preferred over waste storage. For example, radioactively contaminated metal must be collected to Paldiski interim storage and when a sufficient volume level is reached, the waste must be sent for remelting to a country engaged in it. Concentrated radioactive waste generated in the course of melting is managed in Estonia. Expert assessments serve as the basis for such a practice, showing that decontaminating the metal on site is not effective.

Another option for reducing the volumes of waste is separating waste by type, which, in turn, simplifies management. The management of mixed waste is generally much more expensive and the separation requirement is established on the basis of the IAEA's recommendations also in Estonian law and compliance with it is also checked when processing the radiation practice licence application and in the course of later inspection.

Most of the current waste in Estonia originates from the Soviet Union time, which is why the volume and activity of the waste is sometimes difficult to assess. Therefore, the most urgent national activity when reducing the volumes of existing as well as generated waste is related to the characterisation of waste.

The precise data received as a result of characterising the waste gives the answer on which part of the existing waste can be cleared in the future and which part is subject to final disposal. This allows to save resources and the burden on the environment is also reduced. According to the Radiation Act, the radioactive substances generated in the course of radiation activity, if they are with such a low activity or activity concentration that their management and storage as radioactive waste is not necessary from the point of radiation safety, they may be exempted from the requirements of the Radiation Act. The indisputable precondition of releasing is the characterisation of waste (ascertaining the radionuclides and activity concentrations). To this end, it is necessary to create a system for characterising other waste in addition to sealed radiation sources and develop necessary clearance procedures. The clearance of waste also allows optimising the amount of radioactive waste that is subject to final disposal, which, in turn, also means better use of existing financial means.

3.3. *Waste management*

The reduction of the generation of radioactive waste and primary management begins at the holder of the radiation practice licence. Waste volumes can be reduced in the way already described above – by returning the waste to the manufacturer. It is also possible to hold the short-lived waste at the licence holder's place until the activity has decreased below the clearance levels established with the Radiation Act. In exceptional situations, for example, in hospitals, it is also possible to implement on-site management, dilution, etc. This all takes place on the basis of national legislation and a radiation practice licence.

Radiation sources, which cannot be returned to the manufacturer or exempted from the requirements of the Radiation Act, will continue to be managed in Paldiski national radioactive waste treatment centre and thereafter stored in the interim storage located in the same place. On the basis of the Act, the holder of the radiation practice licence has an obligation to deliver the waste to the storage site within five years from generating it. This requirement does not apply to NORM waste, since the Environmental Board decides the way of management of NORM residues and waste separately each time in the course of processing the radiation practice licence application. Such a difference in comparison to other radioactive waste is due to the fact that NORM residues and waste have very different contents in terms of physiochemical and radiological characteristics, which is why their ways and options of management differ significantly from the management of other radioactive waste, i.e. they can be processed, mixed, diluted, dispersed, etc. with greater likelihood. For this reason, the generation of NORM waste is only allowed in exceptional situations, if the radiation safety assessment confirms that considering economic, social and environmental aspects the generation of waste is the best solution. For example, if possible, the changing of the filter materials of waste water treatment plants should be planned so that it would take place before superseding the exemption level established with the Radiation Act. In such a case, this material does not have to be managed according to the requirements of the Radiation Act. This requirement is necessary, as considering the principles of radiation safety, it is very difficult to justify NORM waste generated in the course of water treatment. So far, there have not been any problems with the NORM waste of construction materials in Estonia, however, the monitoring of construction materials must be continued according to the new Directive 2013/59/EURATOM.

The question of storing NORM waste is not topical at the moment, since the NORM waste generated in industry is sent out of Estonia as secondary raw material according to the radiation practice licence and the residues generated in water treatment are dispersed, if possible. At the same time, the new Directive is likely to increase the circle of NORM residue generators and therefore, additional surveys have to be carried out on whether the system currently in force is enough or should NORM waste be taken into consideration when constructing a final disposal site as well.

Sealed radiation sources are generally not separately processed in Estonia. If they cannot be returned to the manufacturer, they are stored in Paldiski radioactive waste interim storage, where A.L.A.R.A. AS, which is under the administration of the Ministry of Economic Affairs and Communications, is engaged in their management. The undertaking characterises the collected liquid waste, as a result of which future management can be planned. The activity concentrations of the waste are most likely below the clearance levels and they must be managed as hazardous waste after clearance. The volumes of liquid waste generated in the future are so small and random, that it is not practical to obtain expensive liquid waste management technology for it. The solidification of liquids by way of concreting must primarily be used if that type of waste is suitable for it by its chemical composition, and also the tactics of waiting for radioactive decay. The liquid waste generated will be stored in an indestructible collection container and afterwards in a metal barrel surrounded by absorbent in Paldiski interim storage.

As noted in Chapter 5 of the programme, the Estonian waste streams are small and the selection of suitable management methods is relatively limited. To reduce volume, waste already generated is almost impossible to be processed, for example, burned, remelted, machine compressed. Investment into such waste processing technologies is significantly greater than, for example, constructing a final disposal site close to the ground, however, large investments into voluminous processing technologies are not the best solution considering the small volumes of waste streams taking into account economic, social, and environmental aspects. At the same time, certain management techniques are still in use (compressing and conditioning waste through concreting) and their aim is to ensure the long-term safety of waste.

Therefore, even though Estonia is open to discussions, for example, on the topic of a regional final disposal site, the radioactive waste management policy has been currently built on the principle that the radioactive waste generated in Estonia is managed and disposed on site. The national policy also provides that radioactive waste should not be transported to Estonia for disposal. Both mobile management services (for example, the machine compressing of waste) as well as services offered outside Estonia (for example, the remelting of radioactively contaminated metal) may be used for management, however, the concentrated waste generated as a result of this process is still brought back to Estonia for storage.

According to the national policy, a final disposal site of radioactive waste must be established in Estonia by 2040. The results of the preliminary studies that will be completed in 2015 have an important part to play in the choice of the concept of the final disposal site and the decommissioning of the reactor compartments of Paldiski nuclear site. Thereafter, the environmental impact will be assessed with the aim of ascertaining the location of the storage site and other conditions of waste storage. The planning of the final disposal_site and applying for activity licences should take place from 2027–2037 and the construction from 2037–2040. Thereafter, it is possible to commence the decommissioning of the reactor compartments. The new final disposal_site should be ready by 2040, when the storage time of the reactor compartments will be reached (50 years; use was ended in 1989).

Until the construction of the final disposal site, the radioactive waste is stored in Paldiski interim storage and the reactor compartments of the nuclear site are stored in a conserved form. If the construction of the final disposal site is delayed, it must be decided by 2037 whether it is necessary to take additional measures for the safe storage of the reactor compartments and radioactive waste, for example, to reconstruct the building.

A thorough updating of law must also precede the construction of the final disposal site, since the current legal framework is insufficient for constructing the final disposal site. In addition to the Radiation Act and the regulations issued on its basis, the legislation concerning planning and constructing of constructions must also be changed with the aim of establishing the requirements for the construction of the final disposal site.

3.4. *Effect of the new activities on the national policy*

Over the next years, the launch of new activities is not precluded, for example, in the field of the making of radiopharmaceuticals related to nuclear medicine, which would definitely also affect the radioactive waste streams and sizes characterising them. At the same time, a very extensive activity, which would affect the national policy, is not foreseen in the next years. If the radioactive waste streams should significantly change, the radioactive waste policy and programme must also be reviewed.

3.5. *Resources necessary for implementing the policy*

To ensure the safe management of radioactive waste, technical, financial, and human resources are necessary. Sustainable financing must be ensured primarily for the final storing of waste, as the activity must be financed for years after the generation of waste. For safe management, different finance systems can be used to ensure the existence of all the necessary means. The law in force establishes that the generator of waste is responsible for waste management, and a system for requiring a financial collateral has also been created. It is also planned to enforce the new Radiation Act in 2015, as a result of which the permit holder has an obligation to return high-level radiation sources to their manufacturers. This is common practice in other countries, and several European Union Member States have established the same requirement. The question on how to ensure the safe management of the so-called historic radioactive waste is much more complicated. This is radioactive waste, which originates from the Soviet Union era – mainly radioactive waste that was generated during the decommissioning of Paldiski and Tammiku sites –, to which the principle that the generator of waste must cover the expenses necessary for the safe management cannot be applied. The state must ensure the management of such waste and if possible, the means of EU Structural Funds are used in addition to state budget resources.

Qualified personnel is needed for the responsible management of radioactive waste. This can only be ensured with the consistent in-service training of the Worker. This, however, requires the creation of a new system, since the field of training and in-service training is currently modest in Estonia.

3.6. *Involving the public*

Since the activities related to radioactive waste, especially the construction of the final disposal site are currently under the attention of great public interest, the public must be involved in the initial stage of the activities in order to avoid problems in the future.

4. Milestones and timeframes of the planned activities

The solving of questions in relation to the safe management of radioactive waste is a long-term process. Considering the nature of the existing waste in Estonia, decisions made so far and also the economic situation, it is likely that the most time- and capital-consuming activities (decommissioning the reactor compartments and constructing the final disposal site) will take place during the period of 2037–2050. For the more even distribution of time and resources, the preparations need to already be commenced now.

The main areas of activity of safe management together with explanations and potential expenses will be determined in the period of 2015–2050.

1. Long-term safe management of radioactive waste

The long-term safe management of radioactive waste is ensured with increasing the capacity of the state through specialising and training workers. Legislative drafting analysis and supplementing legislation, including for taking the final disposal site into use, also have an important position. Additionally, it is vital to determine the conditions of the import/export and transit of radioactive waste, waste management responsibility and conditions of environmental monitoring of management places, to specify the minimal security requirements and requirements of physical protection and developing the bases of categorising radiation sources, supplementing and adding provisions about NORM materials, residues, and waste. To ensure the safe management of radioactive waste, continuous improvement of the radiation control system and the maintenance of the existing interim storage takes place.

The decision for constructing the final disposal site of radioactive waste must be taken on the government level by 2017. Taking into account the radioactive waste existing and generated in the future (including waste generated when decommissioning the reactor compartments), possible disposal options must be considered and the best solutions for Estonia ascertained. When making the selection, it is important to consider local circumstances and also socio-economic factors. To this end, an environmental impact assessment will be carried out from 2017–2027 (hereinafter *EIA*), in the course of which alternative options for the long-term safe storage of waste will also be assessed. Applying for activity licences, planning, building and applying for a use permit of the final disposal site complex, where there also are facilities for waste management and packaging and temporary storage in addition to the storage site, will take place from 2020–2040 on the basis of the EIA results. The final disposal site will be taken into use in 2040.

The environmental impact of the removal of the reactor compartments located in the main building of Paldiski former nuclear site is assessed from 2017–2027. Earlier preliminary studies for the removal of the reactor compartments are taken into consideration in the course of these activities, technical solutions are assessed and the most suitable of them is ascertained. The principles of radiation safety and socio-economic factors have to be taken into consideration when making the decision. Activity licences for the removal of reactor compartments are applied for from 2027–2040 and the reactor compartments will be removed, generated radioactive waste processed and packaged and stored in the final disposal site by 2050.

The safe inclusion of Tammiku radioactive waste storage will take place from 2006–2022 – waste will be removed from the storage, the storage will be decontaminated, demolished, and cleared for general use.

The communication strategy for the construction of the final disposal site and the removal of the reactor compartments is prepared and implemented from 2017–2040, establishing the goals of communication and identifying target groups. The strategy contains a plan for the future activities.

The expenses for the period of 2016–2050 for carrying out the listed works are expected to be approximately 127.208 million euros. Approximately 40 million of it will be spent on planning and constructing the final disposal_site and approximately 60 million on the removal of the reactor compartments.

2. Reduction of the generation of radioactive waste

To reduce the generation of radioactive waste, the preparation and accreditation of the measurement methodologies for characterising waste, purchasing necessary measuring devices, and training personnel and developing all the necessary procedures for clearing waste are in the works. Consistent characterisation of waste with the aim of maximum reduction of the amount of waste before their final disposal_and the suitable processing and packaging of the characterised waste (including sealed radiation sources and soft waste that can be compressed), which allows for their further storage in the interim storage or final disposal_site, is planned for 2018–2050. The development of the radioactive waste management equipment park and the purchasing of the packages necessary for storing waste is planned for 2018–2020. Contaminated metal is continuously collected into the interim storage and sent for remelting. This will most likely take place twice in the period of 2015–2050. Concentrated waste left over from melting is appropriately processed and packaged, which allows for its further storage in the interim storage or final disposal_site. To ensure the safe collection of orphan sources and their consistent management, the management system of orphan sources is constantly developed and kept in operation.

The expenses of carrying out these duties from 2015–2050 are expected to be approximately 12.142 million euros. The greatest expense (estimated at 2.5 million euros) is calculated for 2018–2020, when according to the plan, the collection and remelting of contaminated metal waste takes place.

3. Determining the areas of generation of NORM waste and ensuring its safe management

To ascertain the areas of generation of NORM waste and ensure its safe management, constant collection of information of the generation of NORM residues and potential waste and its management takes place. The need to take additional measures, including if and how it is possible to reduce the generation of NORM waste more effectively nationally, manage generated waste, etc., is planned to be analysed on the basis of the information collected from 2018–2019. After the collection of new data, the part of the programme concerning NORM waste is reviewed and updated if necessary. The monitoring of the radioactivity of drinking water filter materials, with which the generation of NORM waste from the filter materials of drinking water handlers is ensured for 2018–2050 and if necessary, the monitoring and quality checking of construction materials, as well to avoid taking into use construction materials with heightened radioactivity and the generation of later waste. During this period, the constant follow-up monitoring of the remediation project of Sillamäe waste storage facility (tailing pond) is ensured. Pursuant to the agreement, Molycorp Silmet AS will give the production residues generated in the course of its activities over to the parent company in the United States of America as secondary raw material. If new information is received according to which the residues are not taken out of Estonia or Molycorp Silmet AS requests to start generating NORM waste again after 2018, the NORM waste final management plan has to be established nationally before issuing a new radiation practice licence.

Approximately 146,000 euros will be spent on the specified works from 2015–2050. The annual monitoring of the radioactivity of Sillamäe waste storage facility (tailing pond), which costs about 40,000 euros per year, is not included in this amount.

4. Increasing the awareness related to radioactive waste

The increasing of awareness related to radioactive waste is ensured through various activities during the entire period (2015–2050). The preparation of information materials and disclosing thorough multilingual information is important: where and in which fields radioactive waste is generated, what are the options for its management depending on the types and characteristics of radioactive waste, what are the requirements for radioactive waste management, how such activities are regulated, what are the procedures of the choice/preparation of the final disposal site, how the management of radioactive waste affects surrounding residents, etc. During the period, the experts engaged in radioactive waste are trained, training exercises for reacting to radiation emergencies related to radioactive waste are organised and development in the field of radioactive waste is pursued. Since so far, such development has not happened in a coordinated manner in Estonia, the participants and their interests will be mapped. Joint interests are mapped on the basis of the participants' needs and, for example, further research or the preparation of projects is planned on that basis. Meetings, which ensure the consistency of research and development and also promote information exchange, are organised regularly once a year on the initiative of the Ministry of the Environment.

The costs of these works in the period of 2015–2050 are expected to be approximately 656,000 euros, of which a greater part (nearly 490,000 euros) is spent on the preparation of information materials and raising the population's awareness.

5. Inventory

5.1. Existing and necessary means

Technical, financial, and human resources are necessary for ensuring the safe management of radioactive waste. The need for human resources in different stages of activities are assessed in the programme and the system to ensure these needs is described. Financial means are very important when choosing technical options, primarily in the final disposal_stage, when the activities still have to be financed years after the generation of the waste. Several financing sources are used to ensure safe management (means of EU Structural Funds in addition to state budget funds as well).

The treatment sites of radioactive waste include:

- Paldiski radioactive waste treatment facility;
- Tammiku radioactive waste storage facility;
- Molycorp Silmet AS radioactive waste (residues) treatment site.

So far, the specialists of the Environmental Board and radioactive waste handlers have been trained primarily in the course of the technical cooperation with the International Atomic Energy Agency. At the same time, the focus of the IAEA cooperation in the European region is concentrating more and more on countries, which need more help than Estonia. People can be trained through the IAEA in Estonia to a certain extent in the future as well, but regular and consistent training cannot be ensured with them. The University of Tartu and Tallinn University of Technology started the preparation of a joint master's curriculum in the field of nuclear energy and nuclear safety in 2010. The curriculum were ready in the universities, however, these were not implemented. The universities mentioned a lack of financial resources and changed priorities in the state's energy economy development plan as the main reasons. When modifying this curriculum, including adding some missing subjects, it would be possible to develop several levels of radiation safety continuing education at a university if there are necessary financial resources. Training must allow covering the needs of those bodies, which are involved in ensuring radiation protection and safety when issuing radiation practice licences and carrying out monitoring. Radiation protection knowledge is also needed by the users of a radiation source and other interested persons (checking of goods on the border and discovering goods containing a radioactive substance, responding to an accident and emergency caused by a radioactive substance). This would allow to nationally train students as well as workers in the field of radiation safety, including radioactive waste management, and to satisfy the need for the preparation of new specialists and periodic continuing education. However, continuing education, especially obtaining practical skills, is therefore still problematic. It is important to ensure the level of the continuing education, technical equipment of practice work, teaching staff and the consistency of training. To realise all this, appropriate requirements need to be added to the legislation considering radiation safety. If possible, foreign experts can be and, of course, should be used as training providers. In case of this option, as well as local training, various information technology solutions need to be used more widely (for example, Skype or e-learning environments). At the same time, attention must definitely be drawn to the training of the local training providers themselves. In addition to gathering knowledge, regular training allows to ensure more professional relationships of the competent body and the holders of radiation practice licences, including bodies active in radioactive waste management.

Research and development in the field of radioactive waste management has not been developed in the Republic of Estonia. This can be alleviated by participating in international projects, working groups, reporting meetings of conventions, etc. and developing cooperation between national participants.

5.1.1. Paldiski radioactive waste interim storage

The receipt, processing, conditioning, and interim storage of radioactive waste takes place in Paldiski radioactive waste treatment facility (the main building of the former Soviet Union nuclear submarine training centre). The treatment facility is located on the Pakri Peninsula, which is situated approximately 40 km west from Tallinn. Conserved reactor compartments are also located in the treatment facility. The construction of the main building of the training centre was commenced in 1960. The first reactor was started up in 1963 and the second in 1980. The work of both reactors was stopped in 1989. Spent fuel was transported to Russia in 1995 and the reactors were surrounded by a concrete sarcophagus. In September 1995, Estonia took over the management of the site and a radioactive waste interim storage was built in the main building of Paldiski site with the assistance of Swedish company SKB to store the radioactive waste generated in the course of deactivating and decommissioning process. In the programme, Paldiski site covers the main building together with two reactor compartments surrounded by sarcophagi, the gate building, garage and chimney, i.e. the entire area surrounded by a concrete fence. From the takeover, the manager of the site has been A.L.A.R.A. AS, who has carried out various works on Paldiski site over the years:

a) Infrastructure of the site was renovated from 1997–2012;

b) Non-radioactive pollution was removed from the site from 1995–2008 (fuel oil pollution, chemicals and asbestos);

c) Waste treatment centre was built in 1997;

d) Solid radioactive waste storage was removed from 1997–2000;

e) Radioactive liquid waste processing complex together with the liquid waste storage was removed from 1997–2004;

f) Redundant buildings and constructions were demolished from 1995–2012, the main building of the site was reconstructed from 2005–2008;

g) The special washing plant and laboratory complex were removed from 2003–2004;

h) Contaminated underground communications (special sewerage pipeline and ventilation pipeline) were removed from 2003–2011.

The waste interim storage and two reactor compartments together with the concrete sarcophagi surrounding them, radioactive waste treatment centre and office rooms are located in the main building of Paldiski treatment facility. The floor and walls of the interim storage are made of reinforced concrete. The walls and floor of the interim storage reach 1 m below the floor level of the main building, the floor is built directly on natural limestone layer. The storage site is divided into two compartments, which accommodate up to 688 containers (Figure 1) and of which 50 % is filled with waste (as at March 2015). Only solid or solidified waste, the activity and specific activity of which is limited according to the waste packages' compliance indicators established with the radiation practice licence, are stored in the storage site.

Figure 1. Radioactive waste interim storage on Paldiski site.

A radio-controlled overhead travelling crane equipped with a special jaw is in use for placing the waste containers into the storage site. Slinging the containers by hand is not possible due to the lack of access roads in the facility. The lifting system used and the peculiarities of the facility's construction allow delivering waste containers that weigh a maximum of 10 tonnes and are equipped with special eyebolts.

All radioactive waste generated in Estonia, excluding radioactive waste containing natural radionuclides (NORM), is managed on Paldiski site. The main part of the stored radioactive waste is formed of the waste generated during the decommissioning of Paldiski and Tammiku sites. The rest is waste received from other establishments and undertakings. According to assessments, significantly more waste will be generated when dismantling the reactor compartments than fit in the existing storage site. For the safe management of radioactive waste, a final disposal site must be completed before commencing the decommissioning of the reactor compartments, presumably from 2037–2040.

5.1.2. Tammiku radioactive waste storage facility

Tammiku radioactive waste storage facility has been closed for storing new waste since 1995. The structure used as a RADON-type radioactive waste storage is located 12 km south from Tallinn in the territory of the Männiku village in Saku County in a sandy pine forest. The structure was completed in 1963. The facility was managed by Tallinna Eriautobaas until 1995. It was however handed over to the management of A.L.A.R.A. AS in 1995. By construction the structure is an underground facility with concrete walls, which had to fit 200 m^3 of solid waste. The volume of the facility is divided into nine sections with concrete walls, the top edge of which is on ground level, the bottom is at 3.2 m depth from the ground. During the active use of the construction, there was a relatively primitive steel roof with locked hatches above the fillable sections. A stainless steel underground container was built for liquid waste, which contained aqueous tritium solution with a very small concentration and which was cleared and the container was emptied and demolished in 2001.

Radioactive substances and radiation sources of industrial, medical and research bodies are stored in the Tammiku radioactive waste storage, including sealed radiation sources in shielding containers, smoke detectors, scrap metal, measuring devices and electric switches with a fluorescent face, various filters, etc. There was also non-radioactive waste, such as mercury lamps and sand. The waste was stored without prior conditioning and sorting. Mainly low-level waste was stored in the facility, except in two metal boxes meant for storing sealed radiation sources located in the sixth section. The effective dose rate of up to 1.2 Sv/h was measured in the top part of one such box. The volume of Tammiku radioactive waste was assessed as 110 m^3 and 97 tonnes. Before the beginning of the decommissioning process, the number of sealed radiation sources was assessed as 18,670 and these radiation sources formed approximately 93 % of the total activity of the facility.

A metal gable-roofed hall has been placed on the facility from 2005.

The expertise of the environmental impact assessment initiated in 2006 recommended that the waste removed from the sections of the waste storage facility and placed in containers should be transported to Paldiski, where its further management, final packaging and further placement in Paldiski interim storage takes place. In 2007, Tammiku radioactive waste storage safe inclusion environmental impact assessment report was approved in 2007 and the safe inclusion works of the facility were commenced in 2008.

The decommissioning works of Tammiku radioactive waste storage facility are viewed in two stages. The removal of the radioactive waste from the facility, pre-sorting and transport for further sorting and management to Paldiski treatment centre took place in stage I (2008–2011). The cleaning of the facility's surfaces from radioactive contamination and the total demolition of the facility took and still takes place in stage II (2012–2017), and the exemption of the facility and its territory from complying with the requirements of the Radiation Act (2017–2022). The first part of decommissioning and its preparatory works have been complied with as a result of which waste has been completely removed from the storage's sections and transported to Paldiski treatment centre, where its further sorting, management and storing has been commenced. With this all, waste has been removed from the storage's sections, which is followed by the second stage of the removal of the storage. Stage II for the decommissioning of Tammiku radioactive waste storage facility, in turn, consists of three parts:

1) Preparing the radiological characterisation (fulfilled in 2012–2015);
2) Cleaning the facility's surfaces from radioactive contamination;
3) Clearing the facility and its territory.

5.1.3. Radioactive waste (residues) management site of Molycorp Silmet AS

Molycorp Silmet AS (former Silmet AS) processes raw material containing natural radionuclides to obtain rare metals and holds the residues containing natural radioactive substances (NORM residues; Naturally Occurring Radioactive Material) generated in the course of this activity. NORM residues are substances, which contain a natural radioactive substance generated as a result of some activity or contaminated with it, the activity or activity concentration of which is greater than the established clearance levels and which is planned to be used again. NORM waste is radioactive waste mainly containing a natural radioactive substance, including NORM residues, which is not planned to be used in the future.

It must be noted that the production residue generated in Molycorp Silmet AS is potential NORM waste as the company plans to use the residues as secondary raw material in its parent company. Molycorp Silmet AS submitted a radiation practice licence application in December 2012 together with a NORM residue safe inclusion plan, where it is written that Molycorp Silmet AS plans to deliver the NORM residues generated in the course of radiation activity and before, to the parent company Molycorp Minerals LLC (United States of America), who uses it as secondary raw material in its development project. The NORM waste generated in Molycorp Silmet AS is very special when considering the physicochemical and biological characteristics and so far, its storage in the radioactive waste interim storage managed by A.L.A.R.A. AS has been avoided. The choice of the final disposal_option of NORM waste depends significantly on the total activity of the waste, the activity concentrations of radionuclides, the physicochemical characteristics of NORM waste, interaction with the immobilisation matrix material, hydrogeological conditions of the final facility, etc.

The threshold quantity of the NORM waste generated in a year is up to 48 tonnes, including 0.6 tonnes of ^{238}U and 0.6 tonnes of ^{232}Th with a specific activity of up to 300 Bq/g. The processing of NORM raw material and waste management takes place on the territory of Molycorp Silmet AS. The maximum gross mass of the waste containers used is 460 kg.

5.2. *Existing radioactive waste on Paldiski site*

5.2.1. Amounts, activity and classification of waste stored in the reactor compartments

In the analysis prepared in the course of the European Union project "Safe Long-Term Storage of the Paldiski Sarcophagi & Related Dismantling Activities", it was found that when decommissioning the reactor compartments of Paldiski former nuclear submarine training centre's nuclear site, depending on the way of decommissioning, 720–2,070 m^3 of waste is generated in the future. On the basis of the chosen strategy of up to a 50-year storage, the volume of the waste generated should still be around 900–1,000 m^3. The amounts of the waste generated can probably be specified significantly after carrying out the preliminary studies on the reactor compartments. The waste generated when decommissioning the reactor compartments is classified as short- and long-lived low- and intermediate-level waste according to Regulation No. 8 of the Minister of the Environment. Such waste requires final disposal in a final disposal site near the ground.

Reactor compartment No. 1

High level components are located in the removable part of the reactor, such as the compensation lattice, reactor chamber together with the shell and screen, and biological protection (water) container.

In 1995, the representatives of the Russian Federation placed a certain amount of radioactive waste, including sealed radiation sources into both reactor compartments in the course of the conservation works of the reactor compartments. The list of this waste was prepared in September 1995 and was given to the Estonian authorities together with other documentation when delivering the nuclear site. On the basis of this list, most of the radioactive waste in reactor compartment No. 1 is surface-contaminated low-level waste (rags, metal waste, tools, etc.). The amount of this waste in the reactor compartment is approximately 14 tonnes. Additionally, about 100 sealed radiation sources (used for calibrating radiological measuring devices) were stored in some chambers of this section in five concrete containers. The containers contained:

1. Neutron radiation sources: ^{238}Pu-^{9}Be, ^{252}Cf;
2. Gamma radiation sources: ^{60}Co, ^{22}Na;
3. β-radiation sources: ^{36}Cl, $^{90}Sr/^{90}Y$, ^{137}Cs, ^{204}Tl;
4. α-radiation sources: ^{239}Pu.

The activity of plutonium and caesium sources was in the range of a few kBq up to a few MBq. The total activity of the radioactive sources located on the nuclear site and stored in reactor compartment No. 1 was about 4.4 TBq (mainly ^{60}Co) in 1995. All these sources have been placed in concrete containers.

Reactor compartment No. 1 contains additionally approximately 1,370 l of radioactive water. A total of 360 l of it originates from the primary circuit. The activity of the water in the primary circuit is approximately 2.2 MBq/l. The time of determining the estimated activity is probably 1989 and the main radionuclides found in the water are ^{137}Cs, ^{60}Co, ^{90}Sr, and ^{3}H.

After emptying all the cooling circuits of water, an estimated of 1,000 l of water with a very low activity concentration (approximately 4 Bq/l) was left in the steam generators of the secondary circuit. There is approximately 6 l of water in the fourth circuit. There is no data about the potential amount of water left in the third circuit.

Reactor compartment No. 2

The waste stored in the reactor compartment is mainly surface-contaminated textile, metal waste, tools, etc. Very low-level radioactive lead (lead carbide PbC) and ten PKI isolation chambers (length 4 m) were also stored in reactor compartment No. 2. The amount of the specified waste is approximately 2.5 tonnes. According to Technicatome & BNFL (2000), sealed radiation sources were not stored in the reactor compartment, however, this claim is not based on documented evidence but private conversations.

This reactor compartment contains approximately 2,285 l of water in addition to solid waste. A total of 600 l of it originates from the primary circuit. Activity is approximately 1 MBq/l. The time of determining the estimated activity is probably 1989 and the main radionuclides found in the water are ^{137}Cs, ^{60}Co, and ^{90}Sr.

According the best existing knowledge, the isotopes and activity of the components and waste in both reactor compartments is presented in Table 1.

Table 1. Estimated amounts of radioactive waste in the reactor compartments; decay as at 31 December 2013.

Radio-nuclide	Total activity, Bq							
	Reactor compartment 1				Reactor compartment 2			
	Sealed sources	Reactor shell	Cooling water residue	Sarcophagus	Sealed sources	Reactor shell	Cooling water residue	Sarcophagus
^{3}H			2.73E+06					
^{55}Fe		3.44E+12		6.95E+04		1.17E+12		
^{60}Co	1.35E+12	2.25E+13	9.53E+05	2.38E+04		6.67E+12	5.55E+04	
^{59}Ni		1.19E+12		3.50E+04				
^{63}Ni		8.66E+13		3.18E+04		3.81E+13		
^{90}Sr	1.58E+07	4.82E+08	4.28E+06					
^{93}Mo		1.61E+08					3.03E+05	
^{137}Cs	4.07E+05		4.35E+06				2.54E+05	
^{152}Eu				9.69E+05		4.86E+12		
^{154}Eu				3.27E+04		3.27E+12		
^{238}Pu	1.62E+11							
^{239}Pu	6.10E+04							
^{251}Cf	1.50E+08							

5.2.2. Waste stored in the interim storage

In addition to the waste generated from the decommissioning of Paldiski and Tammiku site, all radioactive waste generated in all other establishments and undertakings operating in Estonia, which is stored in the interim storage located on the site in concrete and metal containers with external measurements of 1.2 × 1.2 × 1.2 m (volume 1.728 m^{3}).

Metal containers

The concreted waste generated in the course of the decommissioning works made on Paldiski site is stored in metal containers. There are 117 of such containers and their total volume is 202 m^3.

The waste in the containers requires a more detailed characterisation to ascertain, which nuclides are represented in it, and assess its maximum possible activity. Considering that by origin the concreted waste is related to the work of the reactor compartments, it can be presumed that the nuclides presented in Table 1 are found to a greater or lesser extent also in concreted waste.

The waste in metal containers is classified as low- and intermediate-level short-lived waste, which requires final disposal in a final disposal site close to the ground.

Concrete containers

Waste is stored in concrete containers in conditioned (concreted) form, in lead shielding containers, as well as in other packaging (if the sources do not need shielding, for example, sources of smoke detectors, sources of freezing detectors, etc.). The waste originates from the decommissioning works of Paldiski site (1995–2008), Tammiku facility, and other Estonian establishments and undertakings.

There are a total of 146 concrete containers in the interim storage and their total volume is 257 m^3. The waste in the concrete containers is classed as follows:

1. 198 m^3 or 77 % is low- and intermediate-level short-lived waste, isotopes mainly represented – ^{137}Cs, ^{90}Sr, ^{60}Co;
2. 14 m^3 or 5.4 % is low- and intermediate-level long-lived waste, isotopes mainly represented – ^{238}U, ^{241}Am, ^{226}Ra, ^{238}Pu-^{9}Be;
3. 2 m^3 or 0.7 % – NORM waste;
4. 43 m^3 or 16.9 % – unknown uncharacterised waste.

There is indirect evidence about the waste in the final group (origin of waste, dose rates, shape of shielding containers) that this is low- and intermediate-level short-lived waste, but a more precise characterisation is necessary.

Properly described/characterised sources originate primarily from other establishments and undertakings of Estonia and these are sealed radiation sources, of which most are located in shielding containers. The simply identified sealed sources brought from Tammiku facility from 2008–2011 are also in this sub-group (sources of smoke detectors, sources of freezing detectors, sealed sources of ^{137}Cs and ^{60}Co). The containers are not concreted and the waste can be relocated, if possible. Most of the containers only contain one nuclide.

The unknown sealed sources originating from Tammiku are probably ^{137}Cs and ^{60}Co sources in shielding containers. To characterise the waste, the container's window must be opened and the radionuclide determined with a spectrometer and thereafter, it is possible to calculate the approximate activity of the source on the basis of dose rate. Metal contaminated with nuclides radiating alpha particles is metal waste originating from Tammiku, in which at least ^{226}Ra is identified.

Seven containers in the interim storage contain only one source. These are sealed sources, which have been found without a shielding container. In two cases, these are orphan sources and in five cases, a sealed source with a high dose rate brought from Tammiku facility. In some cases additional shielding has been built in the containers (for example, the source is located in a metal pipe in the centre of the container and it is surrounded by sand).

The containers of beta radiation sources contain unknown sources, which the gamma spectrometer and measurements of alpha radiation have not been able to identify. The metal boxes and S-pipe with a high activity containing radiation sources brought from Tammiku facility are collection boxes of sealed radiation sources and the control pipe used for entering sources into the box, which have been taken out of the shielding container (also contains sources).

It may be presumed that the concreted waste from the decommissioning works of Paldiski site is similar to the concreted waste in metal containers. Isotopes presented in Table 1 are probably contained in them.

It can be said about the waste from Tammiku site, which is in concreted containers, that this is uncharacterised waste. Concreted waste is primarily contaminated sand. It can be said on the basis of preliminary measurements that β-active isotopes are strongly represented in them, also probably ^{90}Sr that is widely used in scientific institutions, and there is no α-contamination.

5.2.3. Waste stored on the control area of Paldiski site

Sea containers

In addition to metal and concrete containers, contaminated metal, low-level concrete fracture and 200 l metal barrels are stored in sea containers on the control area of the main building, which contain concreted waste as well as soft, compressed composite waste.

Waste in sea containers is classified as:

1. 389.6 m^3 or 98 % is low- and intermediate-level short-lived waste – low-level short-lived contaminated metal and concrete, isotopes ^{137}Cs, ^{60}Co, and ^{90}Sr;
2. 8 m^3 or 2 % is NORM waste.

The contamination level of metal waste was 0.6–40 Bq/cm^2 in 2012. Approximately 92 % of such waste is from the decommissioning works of Paldiski site. The other 8 % of waste is primarily from the decommissioning works of Tammiku facility and to a very small extent from the metal purchasers in Estonia.

The contaminated concrete generated in the decommissioning works of Paldiski site is stored in the so-called big bags placed in sea containers. By volume, there is 165.6 m^3 of such material and the following circumstances may be mentioned as additional information:

1. α-contamination has not been found on the concrete surfaces, i.e. there are only β- and γ-active nuclides;
2. The cleaning levels of 0.4 (β, γ) and 0.04 (α) Bq/cm^2 were the basis when removing contamination from the surfaces.

200 l of waste stored in metal barrels

Low-level waste is stored in 200 l metal barrels on the control area of Paldiski site's main building (soft compressed waste, wood, small size metal, concreted waste, etc.), which in turn are located in a sea container. The surface dose of the barrels is up to 50 µSv/h. There are a total of 446 barrels of 200 l and 362 of them are filled with waste from Tammiku facility. All waste in these barrels needs characterising.

The waste packaged in 200 l metal barrels is divided by waste type as follows:

1. 85.4 m^3 or 95.7 % is low- and intermediate-level short-lived waste (soft compressed waste, wood, sawdust, metal, concreted dust, asbestos), contaminated primarily with isotopes ^{137}Cs, ^{90}Sr, ^{60}Co;

2. 3.8 m^3 or 4.3 % is low- and intermediate-level long-lived waste (soft compressed waste, metal, faces of indicators), primarily waste contaminated by ^{226}Ra.

Liquid waste

The amounts of stored liquid waste are marginal in Estonia. It is primarily waste from Tammiku waste storage facility and its amount is 250 litres. These are liquids in which biological waste was stored in turn. In addition to the waste from Tammiku, very little amounts of liquid waste from scientific bodies containing organic substances containing ^{14}C (0.4 l–2.47 GBq) and ^{3}H (0.9 l–approximately 10 GBq) isotopes are also stored.

A.L.A.R.A. AS plans to carry out a radiological analysis on the waste after the end of the sorting and managing all the waste removed from Tammiku.

Liquid waste is classified:

1. 99.5 % is uncharacterised waste;
2. 0.16 % low- and intermediate-level long-lived waste;
3. 0.36 % low- and intermediate-level short-lived waste.

Bulky waste generated by the safe inclusion of Paldiski site

Bulky waste, which has been generated on Paldiski site when conserving and preparing the reactors for long-term safe storage, is stored separately from other waste. The reactors' conductor rods with a total volume of 8.5 m^3 and activity of 3.5 TBq are stored in four containers and 8 steam generators with a total volume of 10 m^3 and activity of 0.9 GBq in the nuclear fuel cooling pool. Additionally another 55 HEPA filters with activity of 0.9 GBq and volume of 20 m^3 are stored in a room located next to the cooling pool. Each filter element is located in a wooden box and a concrete belt is cast between the box and the element to avoid the dispersion of contamination from the surface of the element.

The activity of waste has been assessed indirectly (Techicatome & BNFL, 2000) and radioactive decay has not been considered. From isotopes, the radionuclides presented in Table 1 are probably represented. By type, this is low- and intermediate-level waste, however, as more precise characterisation has not been made, then it is not possible to assess whether it is short- or long-lived waste.

5.2.4. Total activity of waste located in the interim storage of Paldiski site

On the basis of the work "Assessment of Radioactive Waste Streams" carried out in 2009 and considering the waste added from 2010–2013, a summary can be made about the radioactive waste stored in the interim storage on Paldiski site (Table 2). The summary covers sealed sources, the activity of which is based on the source's passport or is determined considering the dose rate and distance.

Table 2. The activity of characterised waste stored in the interim storage of Paldiski site (as at 31 December 2013)

Isotope	Activity, Bq	Proportion, %
Sr-90	6.20E+14	68.89

Isotope	Activity, Bq	Proportion, %
Co-60	1.11E+14	12.35
Cs-137	1.56E+14	17.29
Pu-238	1.25E+13	1.39
Pu-239	1.95E+11	0.02
U-238	5.30E+07	< 0.01
Am-241	1.60E+11	0.02
Kr-85	2.77E+10	< 0.01
Ra-226	4.91E+09	< 0.01
Ni-63	1.09E+09	< 0.01
Fe-55	6.66E+07	< 0.01
Pm-147	1.08E+07	< 0.01
Ru-106	8.28E+06	< 0.01
Ir-192	1.05E+01	< 0.01
Eu-152	3.62E+04	< 0.01
Tl-204	2.52E+04	< 0.01
Ba-133	3.02E+06	< 0.01
Na-22	8.22E+02	< 0.01
U-234	2.19E+03	< 0.01
Cd-109	2.57E+02	< 0.01
Th-228	6.40E+00	< 0.01
H-3	2.85E+11	0.03
I-125	4.08E+09	< 0.01
KOKKU	9.00E+14	100

The greatest proportion of the activity of the radioactive waste is formed by radionuclide ^{90}Sr (approximately 68.9 %), the next by proportion are nuclides ^{137}Cs (17.3 %) and ^{60}Co (12.3 %). Of the other nuclides, nuclide ^{238}Pu also has notable activity, which forms up to 1.39 % of the total activity. The total activity of the other 19 radionuclides forms 0.11 % of the total activity of radioactive waste.

High-level sealed radiation sources (HSR) are located in the interim storage in 16 concrete containers. Most of the ^{60}Co and ^{137}Cs sources are stored in separate containers by isotope, but in some containers these sources are stored together to save space. ^{90}Sr and ^{238}Pu sources are located in separate containers. The overview is in Table 3. It has to be added as clarification that these containers are already considered in the concrete container inventory by volume.

Table 3. HSR inventory

Isotope	Total activity, Bq	Number of sources	Number of containers
^{60}Co	1.17×10^{14}	61	6
^{90}Sr	5.11×10^{14}	37	3
^{137}Cs	1.46×10^{14}	350	12
^{238}Pu	1.13×10^{13}	17	2

Among the uncharacterised waste a significant part in terms of activity is held primarily by 2 metal boxes and S-pipe with sealed radiation sources from Tammiku facility (they can be considered as HSRs by characteristics) and 4 containers with the reactors' conductor rods.

According to the incomplete inventory of Tammiku facility, the waste in the facility only contained the isotopes and activity presented in Table 4.

Table 4. The total activity of the waste in Tammiku facility on the basis of entries

Isotope	Activity (1 Jan 2000), Bq	Activity (10 Nov 2013), Bq
^{3}H	1.63E+12	7.51E+11
^{60}Co	4.26E+11	6.89E+10
^{137}Cs	1.70E+13	1.23E+13
$^{152.154}Eu$	8.90E+10	4.32E+10
^{85}Kr	1.30E+10	5.30E+09
^{90}Sr	4.69E+13	3.37E+13
^{14}C	2.70E+12	2.70E+12
^{63}Ni	1.40E+09	1.27E+09
^{226}Ra	4.26E+11	4.23E+11
^{239}Pu	7.10E+11	7.10E+11
^{241}Am	7.10E+10	6.94E+10
TOTAL		5.08E+13

Even though the data about Tammiku waste storage facility is incomplete, it still allows to assess the nuclides stored in the facility and their approximate activity and a greater part of the activity is probably stored precisely in the 2 metal boxes and S-pipe.

A total of 96.3 % of the characterised HSRs are formed of intermediate-level short-lived waste and 3.7 % by intermediate-level long-lived waste.

5.3. *Existing NORM waste*

In Estonia, radioactive material and waste originating from natural sources is generated mainly in the production process of Molycorp Silmet AS, but also as a result of drinking water purification and removing natural construction materials from use.

NORM waste of Molycorp Silmet AS

Molycorp Silmet AS stores the concentrated production residues contaminated with natural radionuclides in 200 l metal barrels in Sillamäe. The amount of these residues at the moment is 255 tonnes (generated from 2004–2013). Approximately 72.5 tonnes of residues are added each year. The total activity concentration of the waste is up to 191 Bq/g (^{238}U and ^{232}Th). The residues consist of a solid rough powder. Molycorp Silmet AS wants to deliver the NORM residues to the parent company Molycorp Minerals LLC (United States of America) by 30 July 2018, at the latest. This company uses it as secondary raw material in its development project. If new information is received according to which the residues are nevertheless not taken out of Estonia or Molycorp Silmet AS requests to start generating NORM waste again after 2018, a NORM waste final management plan has to be set up nationally before issuing a new radiation practice licence. At the moment, there is no NORM waste final disposal site in Estonia.

Drinking water

About 39 % of all groundwater use in Estonia is satisfied precisely at the expense of the groundwater of the Cambrian-Vend water complex (approximately 500 bore wells) and there are no other water supply sources in many local government areas. At the same time, the groundwater of precisely this water complex has the greatest radium isotope content, which the results of researches have also shown. Considering the quality requirements of drinking water (mainly about iron and manganese), the water must be processed in advance. The main problem is the NORM waste generated, as the radionuclides are concentrated on the filter materials in the course of processing. The University of Tartu analysed 18 water companies in 2014 and 2015 with the aim of ascertaining the radionuclide content of filter materials. It became evident that the exemption levels established with the Radiation Act were exceeded in 11 cases out of 18. The research was published in 2015 and the results show that it is an important problem, which needs to be solved. One opportunity is to replace such filter materials before exceeding the level established in the Radiation Act, but due to the half-life of radionuclides, these materials as well may still exceed the values established in the Act after a few years. A greater economic expense is also related to the more frequent replacing of the filter materials. As the University of Tartu only investigated a part of water handlers, it is the Environmental Board's duty to collect data about other water handlers. The need for taking additional measures is analysed on the basis of the collected information, including if and how it is possible to reduce the generation of NORM waste, manage waste, etc. more effectively at national level.

Naturally contaminated metal items

The amount of naturally (NORM) contaminated metal items (e.g. drinking water network pipes) can be considered quite significant. Considering the geological and physicochemical conditions, it is rather a North Estonian problem and it concerns precisely metal pipes. As a lot of pipes have been replaced by plastic pipes in the last decade and this trend continues, the amount of waste generated reduces considerably. It is estimated that the waste amount generated by such pipes can extend to a couple of hundred tonnes. Currently, the pipes collected so far are stored on its territory by A.L.A.R.A. AS. It became evident as a result of an analysis made in 2012 that there is 8 m^3 of such metal waste. These are sent for remelting in 2018. Concentrated radioactive waste (slag, filters) is returned and it must be managed and stored in interim storage.

Mineral construction materials

So far, there have not been problems in Estonia with construction materials with heightened radioactivity. Still, the Ministry of the Environment in cooperation with the Ministry of Economic Affairs and Communications has taken up the plan to map the situation and develop specified monitoring conditions and requirements. The aim is to ensure the thorough monitoring and quality checking of construction materials to avoid the taking into use of material with heightened radioactivity and the generation of waste and if necessary, to also establish additional requirements. The specific activity indexes of the materials used must be < 1 so that the construction waste generated would not constitute radiological risks and so it could be processed as regular waste. The specific activity index is a dimensionless size characterising a material's radioactivity.

5.4. *Short-lived radioactive waste generated in medical institutions*

Radioactive waste is generated in medical institutions as a result of the use of unsealed and sealed sources. Unsealed sources are used in three hospitals in Estonia: East Tallinn Central Hospital (ITK), North Estonia Medical Centre (PERH), and Tartu University Hospital (TÜK).

On the basis of the available information, radionuclides ^{131}I, ^{99m}Tc, ^{18}F, ^{123}I, ^{90}Y, ^{89}Sr, ^{153}Sm, ^{57}Co, and ^{177}Lu are mainly used. The total activity used per year is 4.23 TBq and volume approximately 6 l. The decay of short-lived nuclides used to below the clearance levels happens very quickly (minutes, hours) and usually takes place already inside the patient and thereafter, these isotopes are released into sewerage. Nuclides with a slightly longer half-life (a few days) are gathered into a separate container and released after the decay of the nuclides to below the clearance levels.

From sealed radiation sources, isotopes ^{133}Ba (total activity 47.2 MBq), ^{152}Eu (18.5 kBq), ^{68}Ge (188 MBq), ^{125}I (185 MBq), ^{192}Ir (988 GBq), ^{106}Ru (108 MBq), ^{90}Sr (156 MBq) are used in medical institutions.

Sealed radiation sources are delivered to a handler of radioactive waste after the end of the time of use or cleared, if the activity level has dropped to below the clearance levels.

5.5. *Summary of the radioactive waste existing in Estonia*

By volume, a very large part of Estonian radioactive waste is uncharacterised. There is 985 m^3 of waste in the interim storage and control area of Paldiski site, of which only 51.84 m^3, i.e. about 5.3 % is characterised. Primarily low- and very low-level waste needs characterising. The situation is opposite with the activity of waste. As most of the sealed sources are characterised, an estimated presumption can be made that at least 90 % of activity is characterised.

The data of waste held in the reactor compartments of Paldiski site and removed from there in the future (2040–2050) in the course of decommissioning are incomplete and the known information is primarily based on literary sources. The waste packages generated need more precise characterising during packing. A maximum activity concentration exists for the NORM residues of Molycorp Silmet AS, but if the safe inclusion of the waste is planned to be carried out in Estonia, it must be analysed more precisely. Table 5 describes the situation of the waste existing in Estonia by waste type.

Table 5. Types and amounts of waste existing in Estonia

Type of waste	Amount, m^3	% of all waste
Low- and intermediate-level short-lived waste	875.9	44.9
Low- and intermediate-level long-lived waste	17.6	0.9
NORM waste	23.7	1.2
Low- and intermediate-level waste, uncharacterised waste	1032.0	53.0

Type of waste	Amount, m^3	% of all waste
TOTAL	**1949.2**	

Low- and intermediate-level uncharacterised waste (1,032 m^3) can be considered as part of short-lived waste in primary meaning, as of it:

1. 988.5 m^3 (95.7 %) is from Paldiski site (including reactor compartments, control rods, steam generators and filters), where according to literature, it is primarily specifically short-lived isotopes (< 30 y);
2. 39.7 m^3 of waste is from Tammiku facility and according to the shape of shielding containers/sources and dose rate, these are sources of ^{60}Co and ^{137}Cs;
3. 3.8 m^3 of waste is from Tammiku facility and these are beta sources. These are probably sources of ^{90}Sr as one of the most used isotope.

As the waste is still uncharacterised, conclusions are based on indirect assessments.

Short-lived waste has not been reflected in the table, since the waste is released in the place of use in a few months maximum.

5.6. Radioactive waste generated in Estonia in the future

5.6.1. Sealed radiation sources

As the use of radiation sources in Estonia shows a rather reducing than increasing trend, it can be presumed that the proportion of the so-called institutional waste received from establishments and undertakings operating in Estonia continues to reduce consistently. It also has to be considered that in case of sources with a greater activity in the recent years, a direction has been taken rather towards returning the radiation sources to the country of manufacture rather than storing them on site. The nucleic content and total activity of the sources currently on the national register is presented in Table 6.

Table 6. Radiation sources in the users' possession, 2013

Isotope	Activity (31 Dec 2013), Bq
^{60}Co	1.53E+17
^{137}Cs	6.46E+11
^{85}Kr	3.86E+10
^{90}Sr	1.56E+08
^{63}Ni	2.22E+09
^{192}Ir	9.88E+11
^{106}Ru	1.08E+08
^{133}Ba	4.72E+07
^{192}Ir	5.18E+12
$_{55}Fe$	1.48E+09

Isotope	Activity (31 Dec 2013), Bq
^{222}Cf	1.80E+05
^{109}Cd	7.4E+08
^{241}Am	1.03E+11

The list is not final, as it is possible that there are still sources originating from the Soviet times in circulation, which are not registered on the national register. This is also confirmed by the results of the collection campaigns of orphan sources. As a rule, these are still sources with a very low activity (indicators of devices containing ^{226}Ra, smoke detectors containing ^{241}Am, and ^{239}Pu, etc.) and their amounts are not large.

Considering the radiation sources in use in Estonia and the waste amounts taken over in the recent years, it can be said that an average of 0.1 m^3 of waste a year will be received as sealed sources in the future. It can be presumed that 50 % of them are long-lived and 50 % short-lived low- and intermediate-level waste.

5.6.2. Metal waste

In 2009–2012, A.L.A.R.A. AS received an average of 1.34 m^3 of contaminated metal waste per year from metal purchasers and the Rescue Board. In the future, the increase of the amounts is not perceived, rather the reduction as the state has strengthened the control of transit on the border (measuring gates detecting ionising radiation on the Estonian-Russian border on the railroad, as well as on highways) and the control over the contaminated metal located on the territory of Molycorp Silmet AS has improved significantly (a metal detector at the gate of the territory, the purpose of which is primarily the discovery of theft of precious metal, but which has also strengthened control over taking out other metallic material from the factory's territory).

In the future, NORM waste will form an estimated 90 % of the volume of waste received. A NORM waste stream of up to 0.4 m^3 per year can be expected. Old water and sewerage pipes can mainly be considered the possible source of NORM waste (up to a couple of hundred tonnes by quantity), but no more NORM metal waste has reached A.L.A.R.A. AS in the course of the extensive replacing of water and sewerage pipelines that took place from 2010–2012. It is likely that more active sediment has been removed from the pipes before decommissioning or the concentration of radionuclides has been low enough that the scrap metal purchasers' measuring gates detecting ionising radiation in the collection points do not react to it.

The generation of metal scrap contaminated by artificial nuclides is according to the forecast also rather reducing than increasing and therefore, their proportion of the general volume of metal waste generated in the future has been assessed as up to 10 %. By volume, this amount is not greater than 0.05–0.1 m^3 per year.

The causes of waste generation are not precisely known, as there are no places of generation of metal waste contaminated with artificial nuclides in Estonia. Supposedly, it is the transit of scrap metal through Estonia and a small amount of metal contaminated by artificial radionuclides has got into the clean metal, which the measuring gates located on the border and on the purchaser's territory that detect ionising radiation first do not discover and which are only discovered in the course of sorting scrap metal. By type, this is low- and intermediate-level short-lived waste.

Possible contaminated devices coming from the Molycorp Silmet AS production process must also be considered in the future. A stream of old radioactive metal waste from Sillamäe is not expected, as the devices as well as strategic technology used for enriching uranium were taken to Russia at the beginning of the 1990s and the contaminated metal waste remaining in Estonia was buried in the Sillamäe NORM waste storage facility (tailing pond) from 1995–2005. Potential waste, however, is the installation currently used in the factory, which may become contaminated in the course of the production process. It is surface radioactive contamination and Molycorp Silmet AS has developed a methodology for deactivating materials with surface contamination to reduce contamination on the surface of the materials. A chemical method is used for deactivating. Even though the contamination levels concentrated on surfaces of the devices used are significantly reduced with regular deactivation, it can be presumed that a certain amount of fixed radioactive substance will gather on the surfaces of the devices over the years regardless of regular cleaning. As the accepted contamination levels of scrap metal purchasers at the moment are very low, then there is low probability that the used devices, pipes, etc. can be decommissioned as scrap metal in the future without additional cleaning. Considering the size of the production lines of Molycorp Silmet AS, it can be presumed that the amount of problematic metal is up to 200 tonnes, even if part of the installation can be decommissioned as scrap metal directly. This waste is likely to be generated by replacing the factory's installation at once.

5.6.3. Waste generated in the further decommissioning of Paldiski and Tammiku sites

Waste generated in the further decommissioning of Paldiski site

The amount and activity of the waste kept in the reactor compartments of Paldiski site and removed from there in the future (2040–2050) in the course of decommissioning is described in Chapter 5.2.1.

Waste generated in the further decommissioning of Tammiku site

The waste stored in sections has been taken out of Tammiku waste storage facility and taken to Paldiski site. Only the contaminated concrete constructions remain, the characterisation of which is dealt with by the decommissioner of the facility, A.L.A.R.A. AS. There are 548 m^2 of concrete surfaces that need cleaning. The prior experience of A.L.A.R.A. AS, when cleaning the Paldiski site, has shown that the removal of up to 5 cm concrete layer is generally enough when cleaning high-quality concrete walls to below the clearance levels. On the basis of this, up to 28 m^3 of concrete scrap will be generated when cleaning the waste storage. It is likely it is the maximum possible volume, which may decrease significantly, as waste is not stored in sections 7–9 and the preliminary studies indicate the cleanliness of the sections. In addition, Regulation No. 10 of the Minister of the Environment came into force on 4 March 2005, establishing significantly higher clearance levels for a cleared concrete surface than were at the cleaning works of Paldiski site (for example, in case of ^{137}Cs before the regulation coming into force, it was 0.4 Bq/cm^2 and now 10 Bq/cm^2, in case of ^{226}Ra 0.04 Bq/cm^2 and 1 Bq/cm^2, respectively). On the other hand, a lot of uncertainty is related to Tammiku facility and it may happen that at times surfaces need to be cleaned significantly deeper than presumed so far (floor, connections of walls, and the floor). Therefore, initially the volume of waste generated must still be assessed to be 28 m^3. The waste is generated from 2014–2016. As the radiological characterisation of the walls and floors of the facility is still in progress, nothing else can be added about the type of waste than that it is low- and intermediate-level waste.

The chance that some part of the pollution has distributed into the environment through the facility's barriers cannot be completely excluded. The environmental survey implemented by

A.L.A.R.A. AS has not, however, identified any traces of the distribution of the contamination, but the final answer to this question will only be received in the course of decommissioning the facility.

<u>Secondary waste generated during the management of radioactive waste</u>

Secondary waste is generated in the course of management works at Paldiski site and in the course of decommissioning Tammiku site. Secondary waste generated is primarily protective clothing, protective equipment (masks) and tools used (hoses, plastic, paper, rags). In addition, the dust gathered when cleaning the waste treatment centre. Protective clothing, masks and tools can be decompressed into a 200 l barrel. Approximately 0.1 m^3 of soft decompressed waste is generated from them per year. The dust gathered in the course of cleaning the waste treatment centre located on Paldiski site must be fixed by concreting to prevent the distribution of pollution. About a 20 l plastic bag's worth of dust is generated in a year, which needs concreting. In addition to solid waste, liquid waste, which is collected into containers, is generated as a result of washing the protective clothing, management works and floors at Paldiski site. On average 10 m^3 of liquid waste is generated per year. So far, the specific activity of waste generated has been below clearance levels and these have been possible to be cleared after analyses. Considering the predictions of future, waste generation and the nature of radiation works, it can be presumed, that the same approach will also continue in the future. Considering the nature of the waste managed, it can be presumed that the secondary waste generated is low- and intermediate-level short-lived waste by type.

5.6.4. Liquid waste

As a rule, liquid waste is not generated in Estonia. Its potential sources are research bodies. Generally short-lived nuclides are used in research bodies, which are temporarily stored in laboratories until the decay of radioactivity below clearance levels and thereafter, they are utilised as regular waste or as hazardous waste. Liquid waste requiring long-term storing is primarily of historic origin (waste has been generated in the course of decommissioning works of Paldiski and Tammiku sites) and it appears when removing historical warehouses. Therefore, the streams of this waste cannot be definitively eliminated. It is estimated that the stream of such waste is up to 100 ml per year and by type, this is low- and intermediate-level long-lived waste.

5.6.5. NORM waste

Molycorp Silmet AS collects and packages the NORM residues generated in the process of processing earth metals and stores it on its territory in a warehouse temporarily, about which an environmental impact assessment has been carried out. Due to the specific character of the production process and demand, the waste streams generated are irregular. This is because NORM residues may not even be generated in the production of some metals and in addition the amounts generated vary depending on the raw material used. By the end of 2013, a total of 225 tonnes of production residues has been created and an average of 72.5 tonnes is added each year. It must be noted that the production residues generated is potential NORM waste, because the company plans to use the residues as secondary raw material in its parent company. According to the radiation practice licence issued in 2013, the waste of Molycorp Silmet AS has been called residue, as it can be used as secondary raw material. According to the safety plan submitted by the company, a protocol of intent has been concluded with the parent company MolyCorp Minerals LLC, which uses the residues as secondary raw material in its development project. All residue generated by 30 July 2018 is planned to be removed from Estonia by then, at the latest. Therefore, radioactive waste will not be generated in Molycorp Silmet AS at least until 2018. If new information is received according to which residue is still not removed from Estonia or Molycorp Silmet AS requests to start generating NORM waste again after 2018, a NORM waste final management plan has to be set up nationally before issuing the new radiation practice licence.

5.6.6. Short-lived radioactive waste generated in hospitals

The future streams of such waste will remain the same, i.e. by volume of approximately 6 l with a total activity of 4.23 TBq (see also Chapter 5.4). Short-lived waste is not reflected in Chapter 5.6.7, as the waste is cleared in the place of use within a couple of months maximum.

5.6.7. Summary of the radioactive waste generated in Estonia in the future

The stream of sealed radiation sources in Estonia is reducing. As they still have some application and the register does not include all sources, a waste stream of 0.1 m^3 a year can be considered. The average stream of metal waste of the last five years has been 1.34 m^3. By year, the streams have been exponential due to the waste collection campaigns organised by the state. For example, in 2009 and 2011, when the campaign was not organised, a total of 0.25 m^3 of waste was received, in 2010 and 2012 during the campaign 1.5 and 3.6 m^3 of waste was received, respectively. The volumes of waste will probably reduce in the future, because waste collected over the years has been delivered in the course of the campaigns and there is no new waste in such amounts being generated. The average expected metal waste stream is 0.5 m^3 per year in the future. This is mainly metal waste contaminated by natural (0.4 m^3) and to a lesser extent by artificial nuclides (0.1 m^3).

The waste stream coming from Molycorp Silmet AS in the form of contaminated devices is very difficult to predict. It is estimated that the amount should not exceed 200 tonnes of metal contaminated by NORM waste. The waste should be generated over 20–30 years. The amounts of problematic production residue generated in Molycorp Silmet AS (concentrated NORM waste) is difficult to assess, as it depends on many factors (economic, political, environmental). On the basis of the valid radiation practice licence, the average waste stream of the year is 72.5 tonnes.

Up to 28 m^3 of concrete scrap is expected in the course of the decommissioning of Tammiku facility. The waste is generated from 2014–2016.

Waste streams of 0.1 m^3 (soft decompressed waste) and 0.02 m^3 (waste requiring concreting) can be expected from Paldiski site. This is secondary waste generated in the management of radioactive waste.

The foreseeable streams of liquid waste are up to 100 ml of low- and medium-level waste per year.

It is estimated that by waste type in the future:

1. 0.27 m^3 low- and intermediate-level short-lived waste;
2. 0.06 m^3 low- and intermediate-level long-lived waste;
3. 10 m^3 cleared liquid waste;
4. 0.4 m^3 (contaminated metal) NORM waste and 72.5 tonnes of Molycorp Silmet AS NORM waste (potential NORM waste);
5. 0,1 l low- and intermediate-level liquid waste will be generated.

In addition, the generation of single large-volume waste in Tammiku (28 m^3) and Molycorp Silmet AS (200 tonnes) have to be taken into account.

The waste generated when decommissioning Tammiku facility is low- and intermediate-level, but its temporal classification will become evident after the end of the characterisation of the facility.

5.6.8. Clearing waste

At the moment, only short-lived radioactive waste generated in hospitals and secondary low- and medium-level short-lived liquid waste generated in the course of A.L.A.R.A. AS management works can be cleared in Estonia. All other waste types must be characterised before. After that it should be possible to clear low- and medium-level short-lived waste to a greater or lesser extent (for example, concrete cut from Paldiski site, some soft waste that can be decompressed). As the isotopes in waste are mostly ^{90}Sr and ^{137}Cs, then considering the half-life of these isotopes in the 30–40 year perspective, a significant reduction of the volume cannot be perceived. If materials can be cleared, then it can be done immediately after the primary characterisation. For this a system for characterising other waste as well in addition to sealed radiation sources has to be created and the necessary clearance procedures developed.

6. Concepts or plans and technical solutions from generation to disposal

The planning of radioactive waste management is particularly based on existing types of waste, amounts of waste, and the level of activity. Given that nuclear fuel has been cleared from the reactor compartments, existing waste in Estonia can be considered short-lived low- and intermediate-level waste and long-lived low- and intermediate-level waste according to Regulation No. 8 of the Minister of the Environment “The Classification and the Requirements for the Registration, Management, and Delivery of Radioactive Waste, as well as Compliance Indicators of Radioactive Waste”.

Short- and long-lived low- and intermediate-level waste will also be generated in the future.

Waste handler A.L.A.R.A. AS is currently developing the characterisation capability and a suitable measuring device will be obtained in 2015, and this is followed by the preparation of measuring techniques and staff training. According to the plans, A.L.A.R.A. AS starts with the characterisation of waste in 2018. The characterisation process is started by means of gamma spectrometry (ISOCART, ISOCS, etc.) and followed by alpha and beta radiation measurement in the future, if relevant.

6.1. *Reactor compartments*

According to the 50-year strategy for the storage of compartments, the decommissioning of the reactor compartments of the nuclear site of the former nuclear submarine training centre in Paldiski results in 900–1,000 m^3 of waste in the future. The amounts and activity of the waste to be generated can probably be significantly specified after carrying out the preliminary studies of the reactor compartments from 2014–2015 and these studies, inter alia, specify the amount of waste to be generated, type of waste, and recommended management method. Additionally, the studies also evaluate the amounts of waste to be potentially cleared or taken to the final disposal site and specify the radionuclides and their activity in the reactor compartments.

6.2. *Metal containers*

Concreted waste generated during the commissioning carried out in Paldiski site is stored in metal containers. On the basis of the character of concreted waste (particularly contaminated materials) and the dose rates of packaging, it can be assumed that this is short- and long-lived low-level waste. The waste stored in containers is in a conditioned (concreted) form and its further management is not foreseen. Since it is low-level waste, it is important to assess whether it is practical to store the waste in the final disposal site in the future or wait until the activity of waste falls below the clearance levels as a result of radioactive decay, enabling to clear the waste. To this end, it is necessary to characterise the waste in detail. Since the characterisation process starts with gamma spectrometry, then further activities can be evaluated on the basis of its results. Essentially, two options are possible:

1. if gamma spectrometry reveals that it is not possible to clear the waste in the future due to the activity of waste and/or the presence of long-lived radionuclides, it is no longer necessary to further characterise waste in great detail (determination of alpha and beta emitting radionuclides) and the waste will be permanently stored in the final disposal site;
2. if gamma spectrometry reveals that it is possible to clear the waste in the future due to the activity of waste and/or the presence of long-lived radionuclides, it is necessary to determine alpha and beta emitting radionuclides. It will probably be necessary to take

samples from the waste packaging by destructive method (drilling) and to analyse them. Based on the analysis, it can be determined whether it is possible to clear the packaging or not. In the event of clearance, it is possible to store the packaging in non-hazardous waste storage facility, for example.

6.3. *Concrete containers*

In concrete containers, waste is stored in a conditioned (concreted) form, in lead shielding containers, and also in other packaging (if the sources do not require any shielding, for example, the sources of smoke detectors, the sources of icing detector, etc.). The waste is the result of the decommissioning works of Paldiski site (1995–2008), Tammiku radioactive waste storage facility, and institutions and companies of Estonia. Further activities are also dependent on the type of waste and storage method.

6.3.1. Concrete containers with conditioned waste

Similarly to conditioned waste stored in metal containers, conditioned waste in concrete containers must firstly be characterised and possible further activities include either their clearance or final disposal (see Point 8.2). Additionally, it must be noted that the choice and uncertainty of possible occurring radionuclides in waste originating from Tammiku radioactive waste storage facility is bigger than in waste originating from Paldiski site, since data on waste stored in the facility is insufficient. The list of radionuclides contained in the waste of Tammiku radioactive waste storage facility is significantly explained by the radiological characterisation of the floors and walls of Tammiku radioactive waste storage facility from 2012–2015. This process includes taking concrete samples and determining the occurring radionuclides.

6.3.2. Concrete containers with sealed radiation sources containing ^{137}Cs, ^{90}Sr, ^{239}Pu, ^{241}Am, ^{238}U, ^{60}Co and Pu-Be

Since these are characterised sources, they first and foremost need to be conditioned before they are taken to the place of final disposal. Suitable method is concreting. It is currently still unclear whether the sealed sources will be conditioned along with a shielding container or the sources must be previously removed from them. Concreting with a shielding container is certainly more appropriate and safer in terms of management, since in this case, management is limited only to concreting. However, if the concentration of heavy metals in waste packaging will be limited in the compliance indicators of waste packaging stored in the final disposal site to such an extent that the concreting in lead shielding containers is not possible, the sources must be removed from the shielding container prior to concreting, placed into a concrete container with an additional shielding, and then concreted. In this case, the sources must be taken out of the shielding container in a special shielded chamber, or hot cell prior to concreting in order to ensure radiation safety. Currently, Estonia does not have a hot cell and its acquisition should be considered, or alternatives should be sought (rental).

A concrete container with additional shielding is a standard concrete container, which has an iron or plastic pipe of 200–400 mm diameter placed in the middle and the free external space surrounding the pipe has been filled with concrete. The pipe is filled from the inside by layers of concrete and sources so that the last layer is concrete.

6.3.3. Concrete container with control sources

The concrete container brings together control sources with different isotopes. The sources in the container must be further sorted and separated by isotope. Then, the sources will be already placed by isotopes in separate concrete containers, which include other sources containing the same isotope. This is followed by the waste conditioning already described in Point 6.3.2.

6.3.4. Concrete container with sealed radiation sources containing radionuclide ^{226}Ra

Such waste includes long-lived low-level waste, which will be stored in the final disposal site. International recommendations on the final disposal packaging of such waste have not been developed yet. Only recommendations on the interim storage are available, and according to those recommendations, the waste must be stored in a stainless steel airtight storage container. In the near future, A.L.A.R.A. AS is planning to pack also such sources in a stainless steel container, which also has a stainless steel reinforced frame around it, and that is, in turn, placed in a concrete container. The container has been equipped with a manometer and manually opened valve (to lower the pressure caused by helium resulting from the decomposition of ^{226}Ra, if relevant). Waste packed in such a way is stored in the interim storage until a suitable method for final disposal has been determined. Similarly, it is planned to also store the scales that glow in the dark and are covered with ^{226}Ra-containing paint (particularly aircraft watches, compasses, etc.), which are currently placed in a 200-litre metal barrel.

6.3.5. Sealed sources containing radionuclides ^{85}Kr, ^{3}H, ^{152}Eu, ^{106}Ru, ^{133}Ba

Such sources are kept in one container in the interim storage facility and these sources are subject to the waiting tactics of radioactive decay. After the radioactive decay of the sources below the clearance levels, procedures for clearing the waste will be carried out. As a final result, the cleared waste will be stored in the non-hazardous waste landfill or utilised as scrap metal.

6.3.6. Concrete containers with uncharacterised sources originating from Tammiku radioactive waste storage facility

Each concrete container contains only one unshielded source. Some containers include a built-in additional shielding (for example, the sources is located in the metal pipe in the middle of the container and it is surrounded by sand). Based on the dose rates of the sources, these are probably particularly the sources of ^{137}Cs, or in some other cases, the sources of ^{60}Co that need to be stored in the final disposal site. The sources of ^{60}Co with their relatively short half-life would also be suitable candidates for waiting radioactive decay below the clearance levels and the subsequent clearance. However, given the relatively high dose rate of the sources and therefore, the activity, their decay below the clearance levels may take more than 300 years. Final decisions on the storage of such sources can be made after these have been characterised.

In case of the interim storage (waiting radioactive decay below the clearance levels), it is practical to place the characterised sources in a concrete container together with other similar radionuclide sources. In the event of the final disposal, the sources must be gathered into a concrete container with an additional shielding by radionuclides, and then concreted.

6.3.7. Concrete containers with unidentified sealed sources originating from Tammiku radioactive waste storage facility

The unknown sealed sources originating from Tammiku are probably ^{137}Cs and ^{60}Co sources in shielding containers. This waste must be characterised and then, it can be decided whether the waste should be taken to the interim storage and later cleared, or taken to the final disposal site. Similar sealed ^{137}Cs sources, which are used for industrial purposes, are so active that the time for their radioactive decay below the clearance levels is 700–1,000 years and therefore, it is not practical to take these sources to the final disposal site. The source of ^{60}Co need 100–200 years to reach the clearance level and it is justified to take them to the interim storage and later clear them.

The waste to be stored in the interim storage will be characterised and then stored in their existing form (in a shielding container) on the basis of radionuclide in a concrete container.

In the event of sources needed to be taken to the final disposal site, the issue that has already been discussed in Point 6.3.2. should be taken into account – whether concreting takes place with a shielding container or not – and on the basis of this, it is decided whether the waste packaging must be a standard concrete container or a concrete container with an additional shielding.

6.3.8. Concrete containers with beta radiation sources

Containers with beta radiation sources contain unknown sources particularly from Tammiku waste storage facility. The sources need to be characterised (determination of radionuclide and activity). It may be possible to visually identify some sources by catalogues, however, some of them can be identified only by radiochemical analysis. After the characterisation of sources, it is possible to place identified sources into a concrete container by radionuclides and either take them to the interim storage and clear them or take them to the final disposal site and manage them as described in Point 6.3.2.

6.3.9. Concrete containers with high-level boxes and S-pipe of Tammiku waste storage facility

High-level metal boxes containing sealed radiation sources removed from Tammiku waste storage facility and S-pipe have been placed in three concrete containers, two of which have special size and one is a standard container. This waste must be first characterised and then, it can be decided whether the waste needs to be taken to the interim storage and released, or to the final disposal site. A special shielded chamber, or hot cell is needed in order to open the boxes and sort the sources from a distance.

Then, it is possible to characterise the sources in more detail and based on the results, the sources will be separated according to radionuclides and placed in concrete containers with an additional shielding and taken to the interim storage and cleared, or concreted in order to take them to the final disposal site.

If it is not possible to use the shielded chamber for any reason, their characterisation should be limited to using gamma spectrometry and modelling techniques. In such a case, the characterisation process is followed by a test and filling in the void surrounding the S-tube with concrete mixture, and final disposal. In doing so, problems may arise due to high dose rate on the surface of the containers, which may not meet the compliance indicators of the packaging taken to the final disposal site that are subject to be established in the future. In this case, the metal boxes and the S-pipe should be repacked into a concrete container with a bigger shielding.

6.3.10. Concrete container with a NORM increment core

The NORM increment core originating from the conservation works of Sillamäe waste storage facility (tailing pond) must be characterised by means of gamma spectrometry and based on the obtained results, waste must be either cleared or concreted together with other materials contaminated with alpha-emitting radionuclides and disposed, since the waste contains long-term radionuclides (^{232}Th, ^{238}U).

6.3.11. Concrete container with contaminated metal of ^{226}Ra

A concrete container containing metal, which accommodates alpha-active isotopes, accommodates metal waste originating from Tammiku and at least ^{226}Ra has been identified. Since such waste is managed similarly to other metal waste, this issue has been addressed more in detail in Point 6.4.1.

6.4. *Sea containers*

The sea containers located in the control area of the main building of Paldiski site accommodate contaminated metal and low-level concrete fracture. Additionally, these also include 200-litre metal barrels with concreted, soft compressible, etc. waste, the management of which is described more in detail in Point 6.5.

6.4.1. Contaminated metal waste

The metal waste stored in the control area of Paldiski is located in the sea containers (part of the waste has been placed in 200-litre metal barrels before placing them in the sea container) and concrete container, and their pollution level during the measurements carried out in 2012 was 0.6–40 Bq/cm^2. As at 2012, there was a total of 191 tonnes and 243 m^3 of metal waste stored in Paldiski treatment facility, and upon their management, as an alternative, it is planned to melt them again in the melting facility of Studsvik in Sweden (Studsvik Nuklear AB). During the melting of contaminated metal, most of the pollution will end up in the upper slag layer of the molten metal and it is possible to remove it from the rest of the materials. The metal that has been purified during melting will be recovered as a raw material and the remaining slag and possible metal that is not suitable for melting (estimated volume of 2 m^3) will be sent back to Estonia. It is estimated that approximately 13 m^3 of slag and secondary waste is returned to Estonia and this waste needs to be taken to the final disposal site. Before final conditioning it is necessary to determine the average activity of waste. The radionuclide composition of contaminated metal is determined prior to the melting of material. For the purposes of final disposal, the waste will be concreted in a concrete container.

6.4.2. Contaminated concrete fracture

Concrete fracture has been placed in 30-litre plastic bags, which, in turn, has been placed in big bags and after that in the sea containers. This material needs to be characterised before any further management related decisions. Since the radionuclide-based clearance levels had not been adopted during the early years of the deactivation of Paldiski site, the removal of pollution from the surfaces was based on very conservative clearance levels, namely 0.4 (β, γ) and 0.04 (α) Bq/cm^2. Therefore, it may be assumed that it is possible to clear part of the materials stored in bags immediately after the characterisation process or short interim storage. The rest of the material will be concreted into a concrete container and taken to the place of final disposal

6.5. *200-litre metal barrels*

The 200-litre metal barrels accommodate low-level waste, which does not lead to a higher dose rate on the waste packaging surface than 50 μSv/h. The metal stored in metal barrels has been discussed in Point 6.4.1. and the screens and scales that glow in the dark and are covered with ^{226}Ra-containing paint in Point 6.3.4.

6.5.1. Soft compressible waste

For the purposes of reducing the volume, such waste has been compressed after being placed in the barrel. This waste needs to be characterised. After this, a small part of waste may probably be cleared. However, a majority of waste must be conditioned prior to taking them to the place of final disposal. There are three possible ways for further handling:

a) the barrels are pressed together with a mobile machine press (volume reduction of up to six times) and then concreted in a concrete container;

b) the barrels are concreted in their existing form in a concrete container;

c) the waste stored in the barrels will be sent to be incinerated in some foreign country on the basis of a re-admission agreement, and the remaining ash will be sent back to Estonia, where it is concreted before final disposal.

In case of alpha contaminated soft waste, only options b) and c) apply as solutions.

6.5.2. Wood and sawdust

Wood is biodegradable waste, which produces gases and may destabilise waste packaging. Since this is low-level waste, such waste must be first characterised in order to estimate the time when the activity of waste drops below clearance levels. If it is possible to clear waste in the future, it is reasonable to implement the waiting tactics. If the decomposition time is still too long, it should be considered to incinerate the waste in a foreign country, and concrete and take the returned ash to the final disposal site. There are no alternatives for burning wood that has been contaminated with alpha-emitting radionuclides.

6.5.3. Concreted waste, rust scrap and dust

It is no longer possible to decrease the volume of concreted waste. The waste must be characterised and then either released or placed in a concrete container for final disposal. In the event of such waste, it may be practical to develop a separate container for final disposal, which would accommodate four to six 200-litre barrels. The existing 1 m^3 standard concrete container can hold only one barrel. If it is possible to fill the surroundings of the barrel with other concreted waste (contaminated fracture, contaminated dust, contaminated iron rust, etc.), it may be practical to also use existing concrete containers.

In the event of rust scrap and dust that has not been concreted and stored in 200-litre barrel, after the characterisation process, it will be practical to clear it or concrete it into a concrete container for final disposal.

6.5.4. Beta radiation sources

Beta radiation sources are soft sources on a foil base. The sources must be characterised and after that it is possible to make decisions on interim storage and clearance or final disposal. In the event of interim storage, it is possible to store the sources in their existing form, however, in case of final disposal, it is necessary to compress the sources together in the barrel and then they need to be concreted.

6.5.5. Contaminated asbestos

This kind of waste must be thoroughly characterised in order to identify the pollution levels. Then, it must be assessed whether the activity of waste has decreased or will decrease below the levels of release after which the waste will be released. If the radionuclide composition and/or activity of waste does not permit its release, the waste must be concreted in a concrete container and taken to the place of final disposal. It is definitely worth to also wait the results of the decommissioning work of the reactor compartments before the management of the mentioned waste in order to simultaneously manage the possible asbestos waste that may occur during the decommissioning of the sections.

6.6. *Liquid waste*

Here, it is particularly waste that has been removed from Tammiku radioactive waste storage facility with a volume of approximately 250 litres. This waste is made up of liquids, which, in turn, served as a storage site for biological waste. Waste handler A.L.A.R.A. AS has characterised liquid waste and launched necessary clearance procedures. Upon the clearance of waste, it is handed over to the hazardous waste handler, who will utilise it by means of incineration, since it consists of organic solvents.

6.7. *Bulky waste located in the site of Paldiski*

Bulky waste means waste that includes 4 cylindrical concrete containers with the steering rods of the reactors and 8 steam generators stored on Paldiski site. Additionally, a total of 55 HEPA filters are stored here, which have also occurred during the operation of Paldiski site.

The steering rods of the reactors have been packed in suitable concrete containers for final disposal and these do not probably need further management.

Steam generators contain the radionuclide of ^{60}Co and therefore, it is not possible to melt them again. It is planned to cut up the equipment, determine their levels of activity, and place them into a concrete container. Depending of the activity of the activated metal, the containers are either taken to the interim storage and cleared afterwards or taken to the final disposal site.

The filter elements are to be placed in a concrete container, since the wooden box surrounding the element is not a durable solution in terms of time. Wherever possible, the filter will be previously dismantled as much as possible in order to accommodate as many filters as possible in a single container. Then, the surroundings of the filters will be filled with concrete and another layer of concrete will be casted upon it, and the container will be taken to the final disposal site.

6.8. *Radioactive waste in Molycorp Silmet AS*

The company has planned to deliver the NORM residues that have been generated in the course of the activities to Molycorp Minerals LLC (United States of America) as secondary raw material by 30 July 2018, at the latest.

Potentially contaminated scrap metal – one of the alternatives of cleaning the installation of the factory is melting it in Studsvik Nuklear AB in Sweden. Returned contaminated slag will be concreted into a concrete container and taken to the final disposal site (see Point 6.4.1).

6.9. *Radioactive waste generated in hospitals*

Short-lived radionuclides, which are used in medical institutions, decompose below the clearance levels in a very quick manner (minutes, hours) and this process usually takes place already inside the patient, and then, these isotopes are released into sewerage. Longer-lived radionuclides (days) are collected in a separate container and released after the decomposition below the clearance levels. At the end of their lifetime, the sealed radiation sources used in hospitals will be handed over to the radioactive waste handler, A.L.A.R.A. AS, who will then practice interim storage and clearance or final disposal, depending on the radionuclide and activity.

7. Concepts, plans for the post-closure phase

The Radiation Act establishes that if the licence is applied for the managing of radioactive waste, information concerning the methods to be used upon the permanent termination of the operation of the treatment facility. The Radiation Act also establishes that after the closure of the radioactive waste management site, the Environmental Board shall preserve the documents on the location of the radioactive waste storage site, its planning and the inventory of radioactive waste without a term; it also shall organise radiation monitoring and the control of access restriction as appropriate and shall carry out intervention if based on the monitoring data or upon inspection it is identified that radioactive substances have entered the environment. So far, there has not been any need to formulate the post-closure conditions in a more specific manner, since Estonia does not have a final disposal site and already only its establishment necessarily requires updating the valid legislation. Certain specifications are still planned along with the enforcement of the new Radiation Act in 2015, since former Tammiku waste storage facility must be permanently closed. To this end, the Act specifies that the holder of the radiation practice licence collects and analyses the data on the use of the storage site of radioactive waste and for the purposes of preserving the data, forwards the data to the Environmental Board, which may then on the basis of the submitted data require the holder of the radiation practice licence to present a new application of the radiation practice licence for closing the storage site. Specified terms and conditions of closing the storage place are determined in the radiation practice licence. After the closure of the radioactive waste storage site, the Environmental Board has the obligation to preserve the documents on the location of the radioactive waste storage site, its planning and the inventory of radioactive waste without a term, to organise radiation monitoring and the control of access restriction as appropriate, to intervene if based on the monitoring data or upon inspection it is identified that radioactive substances have entered the environment.

8. Research, development & demonstration activities

Research and development activities in the field of radiation safety has been briefly reflected in the national development plan of radiation safety. Given the small size of the Republic of Estonia and the fact that Estonia does not have any nuclear installations and the waste stream generated in the future is moderate, then Estonia lacks a separate document, which would establish research and development issues in the field of radioactive waste management. While taking into account the implementation plan of the national development plan of radiation safety, it can be argued that the main related issues in the field of research and development are the following:

- the development of procedures necessary for the characterisation of waste;
- the preparation and accreditation of measuring techniques necessary for the characterisation of waste;
- the development of the procedures necessary for the release of waste
- Research and development activities are based on potential funding sources, which, in turn, can be divided into four groups:
- national research funding;
- international funding opportunities;
- structural funds;
- participant funding.

8.1. National research funding

In Estonia, national research funding takes place in the form of institutional and personal research grants. In both cases, the money is allocated from the national budget through the budget of the Ministry of Education and Research. The application for grants takes place in the framework of an open competition according to the terms and conditions and procedures established by the Estonian Research Council and coordinated with the Ministry of Education and Research. The Estonian Research Council also makes the decisions for awarding research grants.

Institutional research funding enables research and development institutions to finance high-level research and development activities, as well as update and maintain the infrastructure needed for this. The right to apply for institutional research funding has been reserved for the research and development institutions with their research and development activities being regularly and positively evaluated in at least one field at the time of application. Personal research funding is a grant allocated for the funding of a high-level research and development project of an individual or research group employed in the research and development institution.

Estonia does not have a research group of sufficient size to apply for institutional research funding related to the radioactive waste management. At the same time, there are options for applying for personal research funding. The only problem may lie in fierce competition arising from lack of funds for research.

8.2. *International funding options*

One of important options for funding research and development activities is the European Union funding programme for research and innovation "Horizon 2020". The aim of this programme is to create new ideas and jobs and to promote growth. The programme includes all the current European Union research and innovation funding instruments: the activities of the Research Framework Programme, the Competitiveness and Innovation Framework Programme, and the European Institute of Innovation and Technology.

The three priorities of the programme:

- Excellent research. The aim is to raise the quality of the European research activities and to ensure the continuation of the world-class research in order to guarantee the long-term competitiveness of Europe.
- Leadership in the industry. The aim is to make Europe a more attractive place for investment in research and innovation by promoting business-related activities.
- Problems of society.

This is already the eighth framework programme. Taking into account the experience of the previous programming periods, it has been concluded that the programme "Horizon 2020" should be attractive to top researchers and innovative companies. This, in turn, requires the simplification of rules and procedures. The simplification of the programme "Horizon 2020" has three main objectives:

- to reduce the administrative costs of the participants,
- to speed up all the procedures relating to applications and grant agreements and
- reduce the rate of financial errors.

The programme includes a separate work programme for radiation and nuclear safety (*Euratom Research and Training Programme*), which serves as the basis for competitions to obtain funding. The work programme reflects topics for the competitions of 2014 and 2015. Among them are also the topics related to the handling of radioactive waste. Although the primary focus is directed to the geological final disposal sites, there are sub-points, which could also be of interest to Estonia. Estonia may not be ready to lead some consortium and organise the preparation of the application, but it certainly has the ability to participate in joint projects. The calls for proposals were announced on 11 December 2013 and the application deadline was 17 September 2014.

8.3. *Structural Funds*

The funding related to the Structural Funds of the European Union have been determined for the period of 2014–2020. An option related to the Structural Funds to support research and development activities in the field of radioactive waste management is, for example, the following activity "Institutional Development Programme for the Research and Development Institutions and Institutions of Higher Education" under the measure of "Increasing the International Competitiveness of Research and Development of Estonia and Participation in Europe-wide Research Initiatives", or the Strategic Development of Institutions (hereinafter *ASTRA*).

The target groups of ASTRA programme are universities and their research and development institutions, public research and development institutions, professional higher education institutions.

The aim of the programme is to increase the competitiveness of research and development institutions and institutions of higher education, as well as the capabilities of serving the society in the areas of responsibilities of institutions and in growth areas of smart specialisation, as well as increasing the effectiveness of the research, development, and higher education system, including through the reorganisation of the structure of institutions.

This programme would serve as the most realistic opportunity to promote research and development activities in the field of radioactive waste.

It is also possible to apply for project-based funding from the Environmental Research Centre, which, in turn, is financed from the European Union funds. This is suitable particularly for the financing of smaller subprojects.

8.4. *Participant funding*

In addition to funding options described above, it is necessary to also include the financial instruments meant for research and development activities in the budgets of the organisations engaged in the radioactive waste management. This ensures the continuity of knowledge and the development of the organisations.

9. Responsibilities, performance indicators

9.1. Participants and their obligations

Pursuant to the Radiation Act, the radiation safety activities are organised by the Ministry of the Environment through the Environmental Inspectorate and the Environmental Board. The Ministry of the Environment develops radiation safety policies and legislative drafting. The Environmental Board reviews the applications of the radiation practice licences and the qualified expert licences, provides services ensuring radiation safety and advises the Environmental Inspectorate, which carries out monitoring and coordinates and controls the use of the environment and natural resources by applying the coercive measures of the state in the cases determined by law.

Additionally, several ministries and ministerial agencies have been involved in the radioactive waste management and related activities:

- The Ministry of the Interior is responsible for the preparation of emergency plans (including radiological emergency) managed by the authorities in its area of government. The governmental authorities within the area of government of the Ministry of the Interior – the Rescue Board, the Police and Border Guard Board, and in cases relating to nuclear material also the Estonian Internal Security Service – participate in liquidation of emergencies within their competence.
- Ministry of Economic Affairs and Communications coordinates the development of the energy sector. A state-owned public limited company, which organises the management of radioactive waste, A.L.A.R.A. AS, belongs to the administrative field of the ministry. The interim storage and final disposal of radioactive waste is organised by the Ministry of Economic Affairs and Communications, which is also responsible for the application of funds under the preparation of the state budget strategy and from the funds of external financing.
- The Ministry of Education and Research ensures the organisation of educational and research activities;
- The Ministry of Finance organises the allocation of national funds and the Estonian Tax and Customs Board, which belongs in the administrative field of the Ministry of Finance, monitors the transport of goods across the border crossing points and manages the network of radiation monitors on the border crossing points.

9.2. Environmental Board

Pursuant to the statues of the Environmental Board, it shall, inter alia:

- in the cases and to the extent provided by law issues environmental permits, permits for the use of natural resources, radiation practice licences, and other permits and licences within its competence;
- if necessary and within the limits of its competence, participates in environmental legislative drafting, also in the preparation of strategies, programmes, and plans thereof, and shall be responsible for their implementation to the extent established by legislation;
- in the cases provided by law, organises the collection, reporting, and forwarding of the environmental and natural resource utilisation data;
- in the cases provided by law, keeps databases related to its area of activity;

- in the cases provided by law, participates in the environmental impact assessment and the strategic environmental impact assessment;
- organises the monitoring of the radioactivity of air, soil, water, and food;
- organises the assessment of the doses arising from the radiation activities of the residents and the reference groups of the residents;
- carries out radiation laboratory analysis;
- ensures the operation of the system for early warning of transboundary radiation hazard pursuant to the procedures provided for in legislation and the terms and conditions of international conventions and agreements;
- acts as a contact point between the Euratom and the IAEA;
- acts as a national data centre in mediating information with the international data centre on the basis of the Comprehensive Nuclear-Test-Ban Treaty;
- organises the activities related to public involvement and environmental education and communication;
- participates in international cooperation, prepares international projects and participates in them within its competence;
- informs the Ministry of the Interior, the Ministry of the Environment, and the Environmental Inspectorate and the public in the cases determined by legislation about accidents and emergency situations which could result in significant damage to the environment;
- participates in the preparation of emergency plans, their testing and resolving possible emergency situations;
- organises environmental communication and education activities.

9.3. Environmental Inspectorate

Pursuant to the statues of the Environmental Inspectorate, it shall, inter alia:

- performs national supervision and applies enforcement powers of a state on the grounds and to the extent provided by law;
- acts as an extrajudicial body conducting proceedings of misdemeanours in the cases provided by law;
- keeps record of the receipt of financial resources of the state received through the inspectorate;
- organises environmental protection guarding service;
- participates in the liquidation of the consequences of an accident threatening the environment in cooperation with other governmental authorities and local governments to the extent and in the manner established by law;
- participates in the management of emergencies in cases and to the extent provided by the crisis management plan of the Ministry of the Environment;
- develops cooperation with natural and legal persons, the state and local government agencies, and the organisations of foreign countries as well as international organisations within the limits of its respective powers;

- resolves issues related to memoranda and statements in its area of activity;
- performs an obligation to disclose information and inform the general public on the basis of and to the extent provided by legislation;
- collects environmental monitoring data, analyses the effects of the legislation in its field of activity and makes suggestions for improvements, participates in the preparation and coordination of new draft legislation;
- participates in the preparation of national programmes, development plans, and financial plans in their field of activity;
- organises training on environmental supervision;
- performs other tasks that have been assigned to it by law.

9.4. *A.L.A.R.A. AS*

The establishment of A.L.A.R.A. AS in 1995 was driven by the need to manage and decontaminate the nuclear site of the former nuclear submarine training centre in Paldiski, which was taken over from the Russian Federation on 26 September 1995. On 1 November in the same year, also Tammiku radioactive waste storage was taken over from Tallinna Eriautobaas, which contained radioactive waste had been generated in the industrial companies, research and medical institutions of Estonia since the beginning of the 1960s. The radiation practice of A.L.A.R.A. AS covers the decommissioning of the sites of Paldiski and Tammiku, as well as the transport, handling, and storing of radioactive waste.

A.L.A.R.A. AS is a 100 % state-owned company that belongs under the administration of the Ministry of Economic Affairs and Communications with its main activities including the following:

- The management and decommissioning of the Paldiski former nuclear site and Tammiku radioactive waste storage;
- The management and storage of radioactive waste generated in Estonia;
- the development and implementation of radioactive waste management projects;
- the provision of services in the fields of radioactivity and radioactive contamination measurement and radioactive contamination deactivation;
- The development and implementation of plans for the conservation and safe dismantling of unnecessary and/or hazardous establishments of Paldiski former nuclear facility.

A.L.A.R.A. AS manages liquid and solid and stores low and medium active short-term and long-term radioactive waste in the interim storage. High-level radioactive waste is not handled or stored. A.L.A.R.A. AS is responsible for the maintenance of Paldiski site and Tammiku radioactive waste storage facility (with its radioactive waste taken to the radioactive waste treatment centre in Paldiski for further management). In addition to the treatment centre, the main building of Paldiski site also accommodates a place of interim storage (used since 1997) and two sarcophagus containing reactor compartments that have not been decommissioned.

9.5. *Radiation practice licence holders*

There are approximately 600 radiation practice licences in Estonia of which issued licences related to the practice of radioactive substance amount to approximately 10 %. The rights and obligations of the licence holder have been established by the Radiation Act and regulations issued on the basis of this Act. Taking into account the legal framework related to radiation practice licences, the issuing authority, or the Environmental Board has the right and option to establish additional terms and conditions in the corresponding radiation practice licence.

9.6. *Qualified radiation expert*

The Radiation Act established the definition of the qualified radiation expert as follows: a qualified radiation expert is a person having the knowledge and training needed to carry out tests enabling doses to be assessed, and to give advice to individuals in order to ensure the effective protection of the individuals and the correct operation of protective equipment. The qualified radiation expert advises the holder of the radiation practice licence in ensuring radiation safety and protecting the health of radiation workers. The Act establishes that pursuant to § 45 of the Radiation Act, only a legal person holding a corresponding licence may operate as a qualified radiation expert.

9.7. *Division of responsibility*

The current legislation does not provide for the exact division of responsibility in the management of radioactive waste and this may cause confusion. The obligations and responsibilities of the participants need to be specified. Additionally, several legislative acts have come into force in the European Union, which, in turn, place additional obligations on the Republic of Estonia and it is also necessary to specify the obligations in order to meet them. The development of relevant procedures and guidelines also facilitates the process of ensuring radiation safety and safe management of radioactive waste. For example, in order to ensure the safety of orphan sources, guidelines have been provided in "Notification of Radiation Sources Found".

It is foreseen that in relation to radioactive waste management, there will be an additional burden in Estonia – preparations are made to establish a final disposal site, as well as to characterise and clear radioactive waste. Taking into account the burden that has been placed on the Ministry of the Environment, the Environmental Board Radiation Safety Department, and A.L.A.R.A. AS, as well as the complexity of the issues related to the management of radioactive waste, it is expedient to train already experienced workers to have a higher number of specialists. This leads to the need for additional workers. For example, the Environmental Board Radiation Safety Department needs at least two specialists, who would be mostly engaged in topics related to the management of radioactive waste. To this end, however, the Radiation Safety Department needs more people, who would take over other duties of employment of the mentioned workers.

9.8. *Performance indicators*

The performance indicators and related time schedules are particularly linked to the national development plan on radiation safety and its implementation plans. Four issues have been discussed under the topic of radioactive waste management in the national development plan of radiation safety:

- Paldiski former nuclear site;
- Paldiski radioactive waste interim storage;
- Tammiku radioactive waste storage;

- radioactive waste containing natural radionuclides.

The activities related to those four topics has been written down in the implementation plan of the development plan with its latest version involving works that must be done from 2012–2015. These include:

- the updating and verification of the action plan on radioactive waste management;
- the preliminary studies of the establishment of the final disposal site for radioactive waste and the liquidation of the reactor compartments located in the main building of the former nuclear site of Paldiski;
- the development of procedures necessary for the characterisation of waste;
- the preparation and accreditation of measuring techniques necessary for the characterisation of waste;
- the acquisition of measuring devices required for waste characterisation and staff training;
- the development of the procedures necessary for the release of waste;
- The handling of radioactive waste located in the former nuclear site of Paldiski;
- the development of the park of radioactive waste handling devices;
- Safe inclusion of Tammiku radioactive waste storage;
- Follow-up monitoring of Sillamäe radioactive tailing pond;
- the establishment of the management system of waste containing natural radionuclides, the carrying out of additional studies, and the involvement of experts.

Additionally, the activity mentioned under the sub-topic of the establishment of the safe inclusion system of radiation sources is also directly related to the management of radioactive waste – agreeing on the methodology of the cost estimate of the safe inclusion of radioactive substance, the equipment containing it, and radioactive waste, as well as developing and operating the management system of orphan sources.

Table 7 has listed the planned activities and intended results until 2050, main responsible bodies, associate responsible bodies (implementing bodies), the time and cost of the implementation of work. The operational costs will be ensured from the funds of the state budget, if possible, and from the external funding sources, if necessary.

Table 7. Planned activities and results together with responsible bodies, executors, periods of implementation, and costs (ME – Ministry of the Environment; MEAC – Ministry of Economic Affairs and Communications; MER – Ministry of Education and Research; MI – Ministry of the Interior; EB – Environmental Board; EI – Environmental Inspectorate; RB – Rescue Board; PBGB – Police and Border Guard Board; ETCB – Estonian Tax and Customs Board; UT – University of Tartu)

No.	Activity	Expected result	Main responsible body	Executor	The beginning and end of implementation	Cost (in thousands of euros) 2016–2050
1.	**The long-term safe radioactive waste management**					127208
1.1.	State capacity building through specialisation and training of staff	Continuous training of the staff of the Environmental Board and A.L.A.R.A. AS	ME; EB	ME; EB; A.L.A.R.A. AS	2020–2050	
1.2.	Analysis of legislative drafting and improvement of legislation	Adding new important requirements to legislation, including for the introduction of the storage site, the development of the requirements of the import/export and transit of radioactive waste, the requirements of the waste management responsibility and the environmental monitoring of management sites, minimum security requirements, specification of the requirements of physical protection, and the development of the principles for classifying radiation sources, as well as adding and amending provisions on NORM materials, residues, and waste	ME; MEAC	MEAC; A.L.A.R.A. AS, ME; EB,	2015–2050	
1.3.	The development of the quality management system of waste management	Constant improvement of the management system takes place in order to ensure the safety of the management of radioactive waste.	A.L.A.R.A. AS	A.L.A.R.A. AS	2016–2050 (continuous)	
1.4.	The management of the existing interim storage	The place of interim storage has been maintained and protected against unwanted attack, which may result in the contamination of the surrounding environment. The implementation of monitoring programmes and the preparation and implementation of action plans on the basis of the monitoring results, if necessary.	MEAC	MEAC; A.L.A.R.A. AS	2016–2050 (continuous)	

No.	Activity	Expected result	Main responsible body	Executor	The beginning and end of implementation	Cost (in thousands of euros) 2016–2050
1.5.	Environmental impact assessment of the place of final disposal of radioactive waste, including alternative options	Taking into account the existing and future radioactive waste (including waste generated during the decommissioning of reactor components), possible options for final disposal must be assessed and optimal solutions must be identified for Estonia. The selection process must consider local conditions and also socio-economic factors. To this end, the EIA is carried out during which also alternative options for safe long-term storage of waste are evaluated.	MEAC	MEAC; A.L.A.R.A. AS, ME, EB	2017–2027	
1.6.	The preparation and submission of an input to make the national decision on the establishment of the place of final disposal of radioactive waste	The decision on the establishment of the place of final disposal of radioactive waste must be adopted at the government level.	ME	ME; EB, MEAC; A.L.A.R.A. AS	2017	
1.7.	Applying for operating licenses for the establishment of the place of final disposal	The operating licenses have been issued for the design and construction of the place of final disposal.	MEAC	MEAC; A.L.A.R.A. AS	2022–2027	
1.8.	The design and construction of the place of final disposal	Based on the results of the EIA, the complex of the final disposal site has been designed and constructed, including also the facilities for the processing and packaging as well as temporary storage of waste.	MEAC	MEAC; A.L.A.R.A. AS	2027–2040	
1.9.	Application for authorisation for use to introduce the place of final disposal	Application for authorisation for use has been issued and the place of final disposal has been introduced.	MEAC	MEAC; A.L.A.R.A. AS	2039–2040	
1.10.	The management of the established place of final disposal	The place of final disposal has been maintained and protected against unwanted attack, which may result in the contamination of the surrounding environment. The implementation of monitoring programmes and the preparation and implementation of action plans on the basis of the monitoring results, if necessary.	MEAC	MEAC; A.L.A.R.A. AS	2040–...	

No.	Activity	Expected result	Main responsible body	Executor	The beginning and end of implementation	Cost (in thousands of euros) 2016–2050
1.11.	Environmental impact assessment of the liquidation of the reactor compartments located in the main building of the former nuclear site of Paldiski	On the basis of previous preliminary analyses for the liquidation of reactor compartment various technical solutions must be evaluated and the best one must be identified. The selection process must consider radiation safety principles, and also socio-economic factors.	MEAC	MEAC; A.L.A.R.A. AS	2017–2027	
1.12.	Application for authorisations for use in order to liquidate the reactor compartments	The authorisations for use have been issued to liquidate the reactor compartments	MEAC	MEAC; A.L.A.R.A. AS	2027–2040	
1.13.	Liquidation of reactor compartments	The reactor compartments have been liquidated, the generated radioactive waste has been processed and packaged and stored in the place of final disposal	MEAC	MEAC; A.L.A.R.A. AS	2040–2050	
1.14.	Safe inclusion of radioactive waste of Tammiku storage facility	Safe inclusion has been carried out in the depository – waste has been removed from the depository, it has been decontaminated, demolished, and cleared for general use.	MEAC	MEAC; A.L.A.R.A. AS	2006–2022	
1.15.	The preparation and implementation of the communication strategy on the establishment of the place of final disposal and the liquidation of the reactor compartments	The communication strategy is completed on the basis of international experience. The strategy provides for the objectives of communication and identifies target groups. The strategy includes a plan for further activities. In future, communication will be based on a strategy that is reviewed on a regular basis and updated, if necessary.	MEAC/ME	MEAC; A.L.A.R.A. AS, ME, EB	2017–2040	
2.	**Reducing the generation of radioactive waste**					12342
2.1.	The preparation and accreditation of measuring techniques necessary for the characterisation of waste	Main gamma spectrometry techniques have been prepared and accredited. This is followed by the preparation and accreditation of measuring techniques of alpha and beta radiation sources.	MEAC	MEAC; A.L.A.R.A. AS	2012–2030	
2.2.	The acquisition of measuring devices required for waste characterisation and staff training	Gamma spectrometry equipment has been purchased and the staff has been trained. This is followed by the acquisition of measuring devices enabling to determine alpha and beta radiation sources and staff training.	MEAC	MEAC; A.L.A.R.A. AS	2012–2030	
2.3.	The development of the procedures necessary for the release of waste	The main procedures have been drawn up and approved.	MEAC	MEAC; A.L.A.R.A. AS	2012–2030	

No.	Activity	Expected result	Main responsible body	Executor	The beginning and end of implementation	Cost (in thousands of euros) 2016–2050
2.4.	The characterisation of radioactive waste	Continuous characterisation of waste with an aim to minimise the waste amount prior to their transport to the place final disposal	MEAC	MEAC; A.L.A.R.A. AS	2018–2050 (continuous)	
2.5.	The development of the radioactive waste management equipment park and the purchasing of the packages necessary for storing waste	The park of the management equipment of radioactive waste is constantly developed, which enables to suitably manage waste for the final disposal. Also, waste packaging necessary for final disposal has been purchased.	MEAC	MEAC; A.L.A.R.A. AS	2018–2020	
2.6.	Conditioning of sealed radiation sources	The characterised waste has been properly processed and packaged to enable their subsequent storage in the place of interim storage or final disposal.	MEAC	MEAC; A.L.A.R.A. AS	2018–2050 (continuous)	
2.7.	Conditioning of soft compressible waste	The characterised waste has been properly processed and packaged to enable their subsequent storage in the place of interim storage or final disposal.	MEAC	MEAC; A.L.A.R.A. AS	2018–2050 (continuous)	
2.8.	Contaminated wood management	The characterised waste has been properly processed and packaged to enable their subsequent storage in the place of interim storage or final disposal.	MEAC	MEAC; A.L.A.R.A. AS	2018–2050 (continuous)	
2.9.	The collection and melting of contaminated scrap metal	Contaminated metal is regularly collected on the territory of A.L.A.R.A. AS and sent to be melted. During the period of action plan, it is expected to take place two times. The concentrated waste that has been left over from melting has been properly processed and packaged to enable their subsequent storage in the place of interim storage or final disposal.	ME / A.L.A.R.A. AS	A.L.A.R.A. AS	2015–2050 (continuous)	
2.10.	The development and operation of the management system of orphan sources	Safe collection of orphan sources and their constant handling have been ensured. The twenty-four-hour reaction capability of the CBRN specialists of the demining centre of the Rescue Board, the radiation specialists of the Environmental Board, and A.L.A.R.A. AS has been ensured.	ME/MEAC	ME, MEAC, RB, ETCB, EB; A.L.A.R.A. AS	2015–2050 (continuous)	
2.11.	The assessment of the effective does of the population caused by the use of open radiation sources	Overview of the use of open radiation sources in medical institutions and laboratories, of liquid radioactive waste generated during the use, and of the doses, which are arising from their management, affecting the general public (for example, sewerage workers, the workers of water treatment plants). Possible recommendations for waste management on the basis of gathered information.	EB	EB	2021–2030	

No.	Activity	Expected result	Main responsible body	Executor	The beginning and end of implementation	Cost (in thousands of euros) 2016–2050
3.	**The identification of NORM waste and ensuring their safe management**					140
3.1.	A comprehensible overview of the generation and management of NORM residues and potential waste	Given Directive 2013/59/EURATOM, information on NORM residues and waste already generated and to be generated in Estonia will be collected	ME/EB	ME; EB; UT	2015–2020 (continuous)	
3.2.	The determination of management volumes and options (opportunities for release and recovery)	Based on the information collected on NORM, the need for additional measures will be analysed, including if and how it is possible for the government to effectively reduce the occurrence of NORM waste, manage the waste already generated, etc.	ME/EB	ME; EB; UT	2018–2019	
3.3.	The updating of the national NORM waste management plan	The radioactive waste action plan provides the basis for reducing the generation of NORM waste After the collection of new data, the part of the action plan concerning NORM materials must be reviewed and updated, if necessary	ME	ME; EB	2019–2020	
3.4.	The monitoring of the radioactivity of drinking water filter materials	As a result of monitoring, finding the best solutions from the perspective of radiation safety in order to avoid the generation of NORM waste and making them safe if it is still generated	EB/EI	EB; EI	2015–2050	
3.5.	The monitoring of the radioactivity of construction materials	To collect information and map the situation and, if appropriate, start with the monitoring and quality control of the construction materials in order to avoid the introduction of heightened radioactive material and subsequent generation of waste	ME/MEAC/EB	ME; MEAC; EB	2015–2050	
3.6.	The monitoring of the radioactivity of Sillamäe radioactive tailing pond	Consistent ensuring of the follow-up monitoring of the remediation project	ME	ME; Molycorp Silmet AS	2015–2050	
3.7.	The management of processing waste of Molycorp Silmet AS and finding a long-term solution	The transferral of processing waste to parent undertaking Molycorp Minerals, LLC; finding a sustainable solution prior to the issuance of a new radiation practice licence	ME/EB	ME; EB; Molycorp Silmet AS	2015–2020	
4.	**Increasing the awareness of radioactive waste**					656

No.	Activity	Expected result	Main responsible body	Executor	The beginning and end of implementation	Cost (in thousands of euros) 2016–2050
4.1.	Timely preparation and submission of international reports	The reports are prepared and submitted in a timely manner	ME	ME; EB, MEAC; A.L.A.R.A. AS	2015–2050	
4.2.	The preparation of background materials and increasing the awareness of the population, including information about the problems and misconduct related to unauthorised shipment and illicit traffic	Disclosure of more thorough multilingual information on where and in which fields radioactive waste is generated, what are the options for its management depending on the types and characteristics of radioactive waste, what are the requirements for radioactive waste management, how such activities are regulated, what are the procedures of the choice/preparation of the final disposal site, how the management of radioactive waste affects the surrounding residents, become aware of the problems and misconduct related to unauthorised transportation and illicit traffic, etc.	ME/MEAC/EB /A.L.A.R.A. AS	ME; MEAC; EB; A.L.A.R.A. AS; PBGB, ETCB	2015–2050 (continuous)	
4.3.	Training of experts engaged in radioactive waste	The preparation of necessary training materials and the organisation of further training sessions for the issuers and holders or the licence, as well as other experts once a year. Separate attention should be paid on training the media in relation with the adoption of the decision of the place of storage	MER/ME	MER; ME; EB; A.L.A.R.A AS; Molycorp Silmet AS, research institutions, radiation practice license holders, experts	2015–2050	
4.4.	Training exercises for responding to radiation emergency situations related to radioactive waste	Responders are trained for being prepared to respond in an emergency situation in a consistent manner; these training sessions teach them to respond to situations related to radioactive waste	MI/ME	MI, ME, MEAC, RB, PBGB, EB, EI, A.L.A.R.A. AS	2015-–050 (continuous)	

No.	Activity	Expected result	Main responsible body	Executor	The beginning and end of implementation	Cost (in thousands of euros) 2016–2050
4.5.	Development activities in the field of radioactive waste	Since such development work has not been done in a coordinated manner in Estonia, it is necessary to map the participants and their interests. On the basis of the vision of the participants, it is possible to map common interest and this serves as a good ground to plan further research or the preparation of projects, for example. Meetings should be held regularly once a year. This helps to ensure the consistent development of research and development, and also facilitates the exchange of information.	ME/MER	ME; MER; EB; A.L.A.R.A AS; Molycorp Silmet AS, research institutions, radiation practice license holders, experts	2015-–050	

10. Cost assessment

The cost estimate particularly highlights the higher costs for obtaining equipment or ordering service work. The assessment does not take into account the costs of waste handler A.L.A.R.A. AS in relation to daily workforce and outsourced materials and services with regard to the maintenance and decommissioning of Paldiski and Tammiku sites, using the funds of budgetary grant in the amount of approximately 0.45 million euros per year. Additionally, A.L.A.R.A. AS provides the safe inclusion of orphan sources and preparedness assurance service, which is financed by the funds of budgetary support (preparedness) and the Environmental Investment Centre (safe inclusion) in the amount of approximately 35,000 euros in a year.

The higher costs of the characterisation, management, and final disposal of waste are particularly related to the following works:

- the development of the waste characterisation system;
- the decommissioning of reactor compartments and the management of generated waste;
- the establishment of the place of final disposal;
- the melting of contaminated metal;
- the acquisition of a concrete knot to condition waste;
- the acquisition of concrete containers for final disposal.

Additional cost leads to possible use of mobile machine press and hot cell (equipment rental) and the incineration of part of the waste service work.

Since the amount of waste generated during the decommissioning of the reactor compartment is of the same size as already existing amounts of waste, it is not possible to prose the best final solution for certain types of waste (soft compressible waste, contaminated wood). There are several alternatives available in the event of compressible waste:

a) the rental of a mobile machine press and the subsequent concreting of the so-called tablets gained from the compression of 200-litre metal barrels;
b) the subscription of waste incineration service and the subsequent concreting of combustion residues;
c) waste volumes are not reduced, but the waste is packed in concrete containers to be concreted.

The waste stream coming from the reactor compartment is very important in choosing a suitable solution, since it provides a general overview of the existing volumes and types of waste, which are not significantly affected by the amounts of radioactive waste generated in Estonia in the future (this on the assumption that Estonia will not start to develop nuclear energy or develop any other waste producing industries).

The cost estimate also estimates that the residues of Molycorp Silmet AS will be sent to the USA as secondary raw material to be recovered and their management as waste and final disposal will not take place in Estonia.

10.1. The development of the waste characterisation system

A majority of waste in the interim storage located on the nuclear site of Paldiski originates from the waste generated during the management and decommissioning of Paldiski former nuclear site and Tammiku radioactive waste storage. This partially consists of conditioned waste packaging, however, unconditioned waste also forms a fairly large part of it – in particular, various contaminated construction residues generated during the cleaning and demolition of contaminated facilities and establishments – concrete fracture, but also wood, asbestos, and other waste, used polythene film, special clothing, etc. Institutional (received from other institutions and organisations) waste of which a majority includes sealed sources represent a modest share in terms of volume, however, these account for a larger part of the stored activity. As a separate group, contaminated scrap metal taken over from metal management undertakings can be observed among institutional waste, characterised by large volume and small specific activity similarly to deactivation waste. There is mostly sufficient basic information (certificates of sources or other similar documents) available on sealed radiation sources, therefore, it can be said that these have been described in sufficient detail and the data can be used as input data in designing the final disposal site of radioactive waste and in preparing necessary safety assessments. However, there are still problems with existing decommissioning waste, which amount to at least 90 % of the volume of existing waste, as well as the liquidation of Tammiku radioactive waste storage facility and the characterisation of (the so-called historic) waste to be generated in the future during the decommissioning of the reactor compartments of Paldiski site. The situation is complicated by the fact that part of the information concerning the waste composition of radionuclides and their activity is missing. As it is often the case with historic waste, reliable describing data on the previous stages of the life cycle of waste is also missing here. The situation is made even more complicated by the fact that at times, the existing decommissioning waste includes already conditioned and previously prepared waste packaging, which is much more difficult to describe than waste that has not been completely conditioned. The analysis "Overview of the Characterisation Options of Radioactive Waste Located in Paldiski interim storage", which was carried out in 2012, found that given the limited resources and main radionuclides found in radioactive waste, it is justified to start with the development of the methodology of waste characterisation from, in situ, gamma spectrometry. As a result of the development of the waste management system, the measuring device will be purchased and the measuring methodology will be developed, which enables to characterise – for example, determine the radionuclides and special activities (Bq/g) of waste – historic waste, which serves as a prerequisite for a later release, or disposal of the waste. Also, staff training on the use of equipment will take place and techniques will be prepared and tested for the assessment of waste packaging with different configuration and of the activity of radioactive waste still not packaged, including the assessment of measurement uncertainty, with the aim of a subsequent clearance of waste or final disposal. The device is planned to be obtained, the measuring techniques are planned to prepared and staff trained during 2015 and all this amounts to approximately 0.3 million euros. After the preparation of the waste clearance methods, the gammaspectrometric characterisation of waste should start in 2018.

If appropriate, in the next stage, it is planned to continue with the characterisation of alpha and beta emitters in the waste packaging (from 2019–2029), the cost of which is significantly higher than gamma spectrometry. Additionally, it must be noted that this field has experienced a significant technical development over the past years and some important changes in measuring systems and methodologies, including their cost, may come over the next few years. Therefore, the forecast of costs for the characterisation of alpha and beta radiation sources is not reliable at the moment.

10.2. *Reactor compartments*

Only the estimate prepared by Technicatome-BNFL over 10 years ago (2001) is available on the cost estimate of the reactor compartments. With regard to costs, this assessment discusses only such scenario in detail according to with the sections will be completely demolished, however, in the course of demolition, only essential cuttings are carried out and waste / waste packaging generated are relatively large. As at 2001, the cost of such a strategy was 14.1 million euros. The strategy recommended by the same working group and chosen by the Republic of Estonia was to completely demolish the sections after they had been preserved for 50 years and to minimise the amounts of waste to be disposed, however, an additional cost estimate was not carried out with regard to this strategy.

The preliminary studies of the decommissioning of the reactor compartments carried out from 2014–2015 will reveal the approximate cost of the decommissioning work. The preliminary studies focus on the scenario selected in 2001 of full demolition of the section and the minimisation of waste.

The preliminary studies are fully financed from the European Union structural funds in a total amount of approximately 1.1 million euros (the studies also cover the establishment of the place of final disposal). The preliminary studies serve as the basis for the beginning of the EIA on the decommissioning the reactor compartments and the establishment of the final disposal site of radioactive waste around 2017. To this end, it is also planned to fully use – up to 5 million euros – the Structural Funds of the European Union (if co-financing is additionally required, then the state budget support funds will be used). On the basis of international practices (Germany, Finland, Hungary), it takes up to ten years to carry out the EIA, meaning that the EIA will be done from 2017–2027.

This is followed by the application of necessary licences and the planning (2027–2037) and construction of the place of final disposal (2037–2040) and the dismantling of reactor compartments (starts in 2040). The estimated cost of the mentioned works must be determined by the preliminary studies that have already begun, therefore, it is not possible to state specific amounts at the moment. However, based on the experience of other countries, it still possible to speak about approximately a total of 90 million euros for which it is planned to use the funds of external financing and state support.

10.3. *The melting of contaminated metal*

The profitability of melting contaminated metal was discussed in "Methodology of the Management of Metal Waste Containing Natural and Artificial Radionuclides", issued in 2012, which revealed that melting is six times more cost-effective management method than long-term interim storage for waiting for radioactive decay and thereafter clearing the waste. The price calculation considered previous consultations with the handlers, waste pollution measurements, waste transport, melting in Swedish company Studsvik Nuclear AB, and the management of returned slag. The total cost of the melting of the existing contaminated metal is 2.51 million euros. The melting is scheduled for 2018.

10.4. *Concrete knot*

Since concreting is essentially the only used technical solution when conditioning waste (except for the management of contaminated wood and soft waste), then a semi- or fully automatic concrete know must be obtained in order to prepare waste for final disposal. Such a knot ensures the stable quality of concrete and compared to hand mixing concrete method, also the levels of doses are slightly lower for the workers.

Modern semi- or fully automatic concrete knot with performance of up to 12 m^3/h costs 35,000–40,000 euros. Given the need for conditioning the waste that is returned after the melting of metal waste, it is necessary to acquire the concrete knot in 2020. After the development of compliance indicators of packaging required for final disposal (by the end of the EIA, or 2027), it is possible to start with the management of concreted waste concreted in the 200-litre barrel, concreted 200-litre barrels and high-level radiation sources for final disposal, which is very much related to the concreting of waste.

10.5. *Concrete containers*

The assessment of the amount of concrete containers needed for final disposal in the future was based on a conservative scenario, i.e. the service for compressing 200 l metal barrels by means of mobile machine press is not ordered and no other technology for minimising the volume of waste (incineration) will be used in addition to the melting of metal. Additionally, a new type of concrete containers storing 200 l concreted metal barrels and accommodating 4–6 barrels will not be acquired, instead, one barrel will be placed in one standard concrete container of 1 m^3; sealed sources will be conditioned together with shielding containers (hot cell is not used); the entire concrete fracture will be concreted. The assessment was based only on existing waste and waste generated during the cleaning process of Tammiku site (approximately 28 m^3 of contaminated concrete fracture will be generated from 2015–2016).

Given the above-mentioned circumstances, approximately 600 additional standard concrete containers of 1 m^3 are needed to dispose existing waste (provided that the existing concrete container used for interim storage is also suitable for final disposal). This is accompanied with 900–1,000 m^3 unconditioned waste from the decommissioning of the reactor compartments. Given that a majority of such waste can be cleared (metal through melting, etc.), the volume of waste to be generated will be reduced, however, later conditioning by means of concreting probably at least doubles the volume of disposed waste (1,800–2,000 m^3) and about 2,000 standard containers of 1 m^3 are further needed for their storage. The price of a single container is approximately 2,500 euros, meaning that approximately 5 million euros is needed to purchase the necessary amount of containers. It is reasonable to start obtaining an additional amount of containers by stages in 2016 in order to avoid major one-off costs. The condition for acquiring containers is the information gained from the preliminary studies of the establishment of the final disposal site on the fact in which containers are best suited for the final disposal of waste.

10.6. *The establishment of the place of final disposal*

Based on a conservative scenario (see point 10.5.), approximately 1,500 m^3 of waste existing in Estonia needs to be taken to the place of final disposal. In the future, this is accompanied by 1,800–2,000 m^3 of concreted waste originating from the decommissioning of the reactor compartments. This means that approximately a total of 3,500 m^3 waste needs final disposal. The stages, time schedule, and estimated cost of the establishment of the place of final disposal has been described in Point 10.2.

Significantly more accurate calculations can be made after the end of the project of the decommissioning of the reactor compartments and the preliminary studies on the establishment of a final disposal site in 2015.

11. Financing scheme

Developed countries, which operate nuclear power stations, have special funds for the final disposal of generated waste and the financing of the commissioning of the stations that collect funds as a part of the price of the electricity sold. In case of institutional radioactive waste, the polluter pays principle is generally recognised, meaning that the waste owner is financially responsible for the management and storage of this waste.

Estonia does not have any nuclear power plants and therefore, no waste management funds have been created. A total of 94.5 % of existing waste is of historic origin (Paldiski and Tammiku sites) and therefore, their safe inclusion is a national responsibility. In the future, their percentage of waste amounts to over 99 %, since further waste streams originating from the holders (institutional waste) are small. In such a situation, it is not reasonable to establish a management fund, since the resources collected there are virtually non-existent and inadequate to solve the problems of waste.

Estonia has implemented the system of financial securities, ensuring that the resources needed for the safe inclusion of used radiation sources are available. Pursuant to § 18 of the Radiation Act, upon applying for the radiation practice licence, the holder of the source shall be obliged to submit an assessment on the safe inclusion of the source, which is prepared by the radioactive waste handler. Then, the Environmental Board considers the economic credibility of the applicant and, where applicable, the amount required to the safe inclusion of the source will be deposited in the bank. The estimation of the cost of the safe inclusion of the source made by the waste handler is based on a developed price methodology, which also takes into account the cost of taking waste to the place of final disposal. Since the new version of the Radiation Protection Act came into force on 10 November 2011, such a system has been implemented only in the last years. Such an arrangement ensures that in case a company goes bankrupt, the state does not have to ensure safe inclusion from its resources. On the other hand, the proportion of such sources is small and this solution does not ensure the funding of final disposal, but rather reduces public expenditure to a very small extent and ensures the equal treatment of the holders of radiation practice licence.

Paldiski and Tammiku sites are state-owned and belong under the area of government of the Ministry of Economic Affairs and Communications (Paldiski site) and the Ministry of the Environment (Tammiku site). For maintaining and decommissioning the sites, the Ministry of Economic Affairs and Communications orders services from radioactive waste handler A.L.A.R.A. AS, which is a national company established particularly for this purpose. In order to finance the service, the funds of budgetary grant are used in the amount of approximately 0.45 million euros in a year. Additionally, A.L.A.R.A. AS provides the safe inclusion of orphan sources and preparedness assurance service, which is financed by the funds of budgetary support (preparedness) and the Environmental Investment Centre (safe inclusion) in the amount of approximately 35,000 euros in a year. These funds are sufficient for the maintenance, decommissioning, and safe inclusion of orphan sources of the sites, however, these are insufficient to finance large-scale projects planned in the coming years, such as the decommissioning of the reactor compartments and the establishment of the final disposal site, the development of the characterisation and clearance systems of radioactive waste (see the implementation plan of 2012–2015 of the national development plan on radiation safety 2008–2017).

From additional public financing mechanisms, the Environmental Investment Centre (EIC) is the most appropriate establishment for the financing of waste management projects. The EIC was established as a foundation on the basis of the Act on the Funds Received from Environmental Use and amending Act in the area of government of the Ministry of Finance in May 2000. Their main activity is to finance environmental projects from the funds received from the Estonian environmental charges, the European Union Cohesion Fund (CF), the

European Regional Development Fund (ERDF), and the European Social Fund (EFS) and to implement green investment scheme (CO_2 sales quotas and mediating subsidies).

One of the drawbacks of the EIC is definitely high-level competition in receiving the grant, since there are quite a lot of areas of concern in Estonia. Therefore, all issues should be addressed on a project basis, and thus ensure their financing.

It is also possible to apply for support from the European Union Structural Funds to carry out projects. The programming period of 2007–2013 has ended and therefore, the funds of the programming period of 2014–2020 will be discussed further on. So far, the Structural Funds have supported projects to the extent of up to 85 % of their cost.

In addition to the EIC and the EU Structural Funds, third possible donor of waste management projects is the International Atomic Energy Agency (IAEA). Although the IAEA does not provide direct financial support for the activities, it offers expert assessments and organises expert missions in the country of location. The missions particularly represent an analysis of the situation and making recommendations on the basis of available information, as well as highlighting possible weaknesses. Therefore, the possible support from the IAEA is rather analytical than material.

12. Transparency policy or process

12.1. *Involvement*

The concept of involvement is based on the assumption that state-level decision-making processes and the drafting of legislation do not only centrally take place among politicians and officials, but more and more citizens and interest groups are also participating in the preparation of decisions and legislation. Involvement in the decision-making processes represents intensive work and it has several forms. Involvement acts as an umbrella, which covers notification, consultation, and participation. The first two are particularly important in terms of radioactive waste management:

- notification – one-sided relationship in which the state informs about its activities and decisions, but the feedback is not expected. At the same time, however, notification serves as a prerequisite to be able to speak about effective involvement and being informed. It is important that the issued information would be adequate, objective, reliable, relevant and easily understood;
- consultation – members of the community can express their opinion and make proposals.

There is a large number of legal acts in the field of the environment concerning involvement. One important way to ensure transparency policy is the process of the environmental impact assessment, which, in turn, serves as a part of the decision process that guides development. In addition to the process of the environmental impact assessment, the Radiation Act provides that in the case of certain radiation practices (including radioactive waste management), the provisions concerning open proceedings apply to the procedure for issue or amendment of radiation practice licences. Open procedure requires, inter alia, that prior to making a decision, the administrative authority must provide the participants in the proceedings an opportunity to express their opinion on the draft or application and submit appropriate objections, and to listen to them. The administrative authority shall determine a deadline for the submission of proposals and objections, which may not be less than two weeks from the beginning of the public display. The Radiation Act provides that the time and location of the public display of the application and draft of the radiation practice licence shall be communicated at least two weeks prior to the beginning of the public display in the official publication *Ametlikud Teadaanded*, in at least one national newspaper and on the website of the Environmental Board.

12.2. *Environmental impact assessment*

The aim of the environmental impact assessment (EIA) is to give decision makers information on the environmental impact of all real courses of action and to propose the most suitable option of solution.

Environmental impact will be assessed if:

- upon application for a development consent if the proposed activity, which is the basis for application for or amendment of the development consent, potentially results in significant environmental impact;
- upon application for amendment of a development consent if the proposed activity, which is the basis for application for or amendment of the development consent, potentially results in significant environmental impact;
- activities are proposed, which alone or in conjunction with other activities may potentially significantly affect a Natura 2000 site.

Pursuant to § 5 of the Environmental Impact Assessment and Environmental Management

System Act, the environmental impact is significant if it is likely to exceed the environmental capacity of the impact area, cause irreversible changes to the environment, endanger cultural heritage, human health and well-being or property. An important part of the EIA process includes public discussions, which must be carried out during the process of the assessment programme and the confirmation of the final report. This means that prior to the approval of the decision maker, the developer must organise a public discussion and to this end, also all documents to be discussed must be made available to interested parties at an early stage. This enables interested parties to make proposals, which require to be also justified in the final environmental impact report if these are not taken into account. Information about the opportunities to participate in the public discussions and obtain access to documents shall be published in *Ametlikud Teadaanded*, however, the main interest groups are often also directly informed. Since many aspects of radioactive waste management have a significant impact on the environment, it is also necessary to pass the environmental impact assessment stage with regard to the application process of the radiation practice licences.

In addition to conventional environmental impact assessment, there is a separate strategic assessment available. The aim of strategic environmental impact assessment (SEIA) is to take environmental considerations into account when preparing and adopting strategic documents. SEIA facilitates high level environmental protection and the promotion of sustainable development. Taking into account environmental considerations must begin already at a time when the main trends of the field and regions are in the planning stage. SEIA enables to prevent later problems by taking environmental issues into account already at a higher level of decision-making. In this case, the EIA serves as already a later specifying assessment at the project level.

SEIA is organised during the preparation of strategic planning documents and plans. Therefore, the general public can participate in the preparatory process of the National Radiation Safety Development Plan through the SEIA process. The organiser of the preparation of the strategic planning document, or the Ministry of the Environment initiates SEIA and is responsible for it, as well as covers all the costs related to it.

12.3. *Ensuring awareness*

In order to ensure that public interests are better represented in decision-making, it is also important for the parties to be better informed about this issue. In order to improve the current situation, more attention must be paid to the development of various information materials and ensure better communication. Additionally, it is necessary to train people directly engaged in the media (both from the side of the operators and the media).

It is possible to find information about radioactive waste management on the websites of the Ministry of the Environment, the Environmental Board, and radioactive waste handler A.L.A.R.A. AS. However, in all these cases, it is relatively static information, which typically includes a short description with references to the legislation. In general, the topic of radioactive waste management has been surprisingly little discussed in Estonia. However, taking into account the expectations of the public, there is a great need to demonstrate available radioactive waste management methods, and it is also important to show the feasibility and effectiveness of different technologies. In addition to theoretical background information, an overview of activities in Estonia in this regard should also be given. Therefore, the websites most certainly need to be upgraded and it is worth considering the use of social media. Such activities lead to additional time expenditure, however, if we base this, for example, on the website of tuumajaam.ee, which ensured a good overview of nuclear power station in Estonian during its short active operation, it could be observed that at least the younger generation developed a better attitude towards the issue. Various participants should also consider planning the upgrading of websites together and for example, divide the topics between themselves and then use mutual referencing on the websites.

The main objective should be raising the awareness of the Estonian population. It is also important to develop and implement a general communication strategy on radiation (including radioactive waste handlers) and more attention should also be paid to improving the awareness of school pupils. In doing so, it is possible to collaborate with various participants, for example, carrying out additional courses in cooperation with Teaduskool or Science Centre Ahhaa. Background materials introducing radiation and radioactive waste management would help people to understand the topic and reduce the fears of the population with regard to ionising radiation (including also the issue of radioactive waste). The preparation of background materials should consider as different target groups as possible – for example, school pupils, residents living near radioactive waste treatment facilities, etc. In addition to traditional printed material, it is also important to prepare background materials suitable for the web environment. The most important step to be taken first is to determine possible target groups and the most suitable ways to reach them. Only good information materials are not enough if there is no idea of their distribution. Here, the development of media plans for different participant could be helpful.

In recent years, little has been published to facilitate learning about ionising radiation. The first activity could be the organisation of an interesting exhibition in cooperation with the Ahhaa centre. One does not have to go far to obtain examples and ideas – it is possible to take a look at the visitor centre of Olkilouto Nuclear Power Plant. In order to ensure successful organisation of such event, the participants (the Ministry of the Environment, the Environmental Board, the radioactive waste handlers, etc.) could join their forces, and such endeavour could also ensure positive media coverage.

Based on the materials published in the media so far, it can be confidently said that there is also a need to train both journalists and potential producers-mediators of radiations news among the radiation protection staff. In order to stand out in today’s world that is overloaded with information, the media staff must have as easy access to information as possible and an opportunity to consult with knowledgeable professionals. In this context, the communication strategy of competent authorities (the Ministry of the Environment, the Environmental Board) and radioactive waste handler A.L.A.R.A. AS is important, since it helps to ensure quick and objective exchange of information.

13. Agreements

The Republic of Estonia does not have any agreements with other Member States of the European Union and third parties in terms of radioactive waste management, including final disposal. The possibility of sending metal contaminated with NORM materials to another Member State of the European Union for processing has been under discussion, since the quantities of metal are so small that the development of the capacity to process them would be too expensive for Estonia. In the event of possibilities under discussion, concentrated waste is returned to Estonia after the materials have been processed in some other countries and their final management would take place in Estonia. With regard to NORM waste, it has been agreed that all resides generated in Molycorp Silmet AS will be carried away from Estonia as secondary raw material.

14. Lead document

14.1. Introduction

In 2011, Directive 2011/70/EURATOM concerning reasonable and safe management of radioactive waste and spent fuel in the European Union came into force, which obliges each Member State to prepare and submit a national programme to the Council, describing the situation of waste management in the Member State and the measures taken from generation to final disposal of waste. The action plan includes a description of the national radioactive waste policy, existing waste inventory, technical solutions for waste handling and storage (final disposal), time frame for the activities, resources, etc.

The general and more specific principles of radioactive waste management have been regulated both at the international level as well as in Estonian legislation. In order to learn and take part in the know-how on radioactive waste management developed at an international level and the international cooperation thereof, the Republic of Estonia has acceded to several international conventions and organisations. The accession to the International Atomic Energy Agency has been a very important step. According to the general principle, in most of the countries, the safe management of radioactive waste is the responsibility of a person who has generated the waste. However, this does not mean that the country itself does not have any obligations in ensuring safe radioactive waste management. In the Preamble of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, the Contracting Parties reaffirm that the ultimate responsibility for ensuring the safety of spent fuel and radioactive waste management rests with the State. The State shall also ensure the control over the use of radioactive sources, including safe management of orphan sources.

The aim of this guidance document is to provide an overview of the national action plan of radioactive waste management and thus, to create a common broad understanding of the issues related to the topic of radioactive waste among the representatives of the interest groups.

The guidance document contains a summary of the following parts of the national action plan:

1. national policy;
2. milestones and timeframes;
3. inventory;
4. concepts or plans and technical solutions from generation to disposal;
5. cost assessment;
6. financing scheme.

14.2. National policy

Basic principles

Radioactive waste management uses both the non-hazardous waste management practices (first two) and also specific procedures:

- concentration and isolation (used if the amounts of waste are large and activity average or great);
- dilution and separation (used for the low activity concentrations and small quantities);
- delay and radioactive decay.

During radioactive waste management it is very important to ensure the minimisation of the amounts of waste to be handled. To this end, it is necessary:

- to keep the amount of generated waste as low as it is possible when taking various factors into account;
- to keep the spread of radioactive contamination under control during radiation activities in order to reduce the possibility that as a result of contamination, the amount of radioactive waste that needs to be managed would increase;
- to optimise the opportunities for processing and recycling of components;
- to implement management technologies to minimise the amounts of waste.

Legislation

In Estonia, the issues of safe management of radioactive waste and emissions are addressed by the Radiation Act and it is complemented by the regulations of the Government of the Republic and the Minister of the Environment. Legislation provides that in case of a high-level radiation source, the applicant of the radiation practice licence shall be obliged to prefer a manufacturer during the acquisition of the radiation source, who agrees to add the requirement on returning the radiation source 15 years after the import of the radiation source to the sales agreement if the activity of the radiation source ten years after its import is higher than 10 MBq. Additionally, each applicant shall submit a plan on the safe inclusion of the radiation source after the termination of radiation source use, indicating the method according to which the safe inclusion of the source will take place in the future. In the event of moderate or high risk radiation practices, the plan shall be approved by a qualified radiation expert.

Transparency of decisions and involvement of the public

The concept of involvement is based on the assumption that state-level decision-making processes and the drafting of legislation do not only centrally take place among politicians and officials, but more and more citizens and interest groups are also participating in the preparation of decisions and legislation. The following are particularly important in terms of radioactive waste management:

1. notification – one-sided relationship in which the state informs about its activities and decisions, but the feedback is not expected. Notification serves as a prerequisite to be able to speak about effective involvement and being informed. It is important that the issued information would be adequate, objective, reliable, relevant and easily understood.
2. consultation – members of the community can express their opinion and make proposals.

There is a large number of legal acts in the field of the environment concerning also involvement. One important way to ensure transparency policy is the process of the environmental impact assessment (EIA), which, in turn, serves as a part of the decision process that guides development. The aim of the EIA is to give decision makers information on the environmental impact of all real courses of action and to propose the most suitable option of solution. An important part of the EIA process includes public discussions, which must be carried out during the process of the assessment programme and the confirmation of the final report. This means that prior to the approval of the decision maker, the developer must organise a public discussion and to this end, also all documents to be discussed must be previously made available to interested parties. This enables interested parties to make proposals, which require to be also justified in the final EIA report if these are not taken into account. Information about the opportunities to participate in the public discussions and obtain access to documents shall be published in *Ametlikud Teadaanded*, however, the main interest groups are often also directly informed. Since many aspects of radioactive waste management have a significant impact on the environment, it is also necessary to pass the EIA stage with regard to the application process of the radiation practice licences.

Agreements

Estonia has acceded to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, which establishes that if the safety of management enables it, then radioactive waste should be taken to the final disposal site in a country in which they have been generated. The Republic of Estonia does not have any agreements with other Member States of the European Union and third parties in terms of radioactive waste management, including final disposal. The possibility of sending contaminated metal to another Member State of the European Union for processing has been under discussion, since the quantities of metal are so small that the development of the capacity to process them would be too expensive for Estonia. In the event of possibilities under discussion, concentrated waste is returned to Estonia after the materials have been processed in some other countries and their final management would take place in the Republic of Estonia. With regard to NORM waste, it has been agreed that all residues generated in Molycorp Silmet AS will be carried away from Estonia as secondary raw material.

Classification of waste

The legislation of Estonia establishes the classification and the requirements for the registration, management, and delivery of waste, as well as compliance indicators of radioactive waste. Types of radioactive waste are the following:

- "cleared waste" – waste generated during the radiation practices with its activity, specific activity or surface-specific activity being smaller than the established clearance levels. These types of waste may be managed the same way as regular waste after their clearance;
- "NORM waste" – radioactive waste generated as a result of the processing of raw material containing natural radionuclides (^{232}Th and ^{238}U, as well as radionuclides belonging to their decay series) with its specific activity being higher than the established clearance levels;
- "Short-lived radioactive waste" – radioactive waste containing less than 100-day half-life radionuclides (for example, ^{192}Ir with its half-life being 74 days), which decompose below the clearance levels for up to five years;
- "Short-lived low- and intermediate-level radioactive waste" – radioactive waste containing less than 30-year half-life beta and gamma emitters (^{60}Co, ^{137}Cs) and a limited amount of long-lived alpha emitters, such as radium needles (not more than 4,000 Bq/g in one waste packaging and not more than an average of 400 Bq/g per total amount of waste).
- "Long-lived low- and intermediate level radioactive waste" – radioactive waste containing greater than 30-year half-life radionuclides with their specific activity being higher than that of short-lived low- and intermediate radioactive waste and for which the amount of heat generated by the radioactive decay is less than 2 kW/m^3.
- "High-level radioactive waste" – radioactive waste for which the amount of heat generated by the radioactive decay is greater than 2 kW/m^3, such as for spent fuel.

14.3. *Milestones and timeframes*

In view of the character of the existing waste in Estonia, the decisions adopted so far, and also the economic aspect of the country, it is likely that the most time and capital consuming activities will be carried out from 2035–2045 (the decommissioning of the reactor compartments and the establishment of the final disposal site). Necessary preparations should be started already in the near future in order to divide the costs more evenly and take into account that part of the preparatory work is extremely time consuming (preliminary studies, the environmental impact assessment, the application of activity licences, the planning of the final disposal site, etc.).

Major milestones in the radioactive waste management in Estonia are:

1. the characterisation of existing waste. The characterisation starts with gamma spectrometry and a suitable device will be probably obtained during 2015. After the preparation of the methodology for measurements and waste clearance, and staff training that will be completed by 2018, the activities of gamma spectrometry can be launched. If appropriate, it will be followed by the next stage of the development of the waste characterisation and clearance systems, which includes the purchase of measuring devices needed for identifying the existence of alpha and beta emitters, the preparation of the methodology for measurements and waste clearance, and staff training. It is planned to be carried out from 2019–2029;
2. the decommissioning of reactor compartment and the establishment of the place of final disposal. Preliminary analysis for the decommissioning of reactor compartment and the establishment of the place of final disposal take place from 2014–2015 and this provides important inputs for the EIA. International experience shows that the EIA of such a sensitive topic may last up to ten years. The EIA is scheduled to be completed by 2027. The planning of the place of final disposal and the application of activity licences are scheduled to be completed by 2037 and the place of final disposal will be completed by 2040. Then, it is possible to start with the decommissioning of the reactor compartments, since the waste generated during this process cannot be placed in the existing interim storage due to its activity and volume, and after the characterisation process, it should be managed and stored in the final disposal site;
3. management of contaminated waste metal. Contaminated waste metal is planned to be melted in 2018. The management of concentrated and secondary returnable waste generated during this process is planned to be completed by 2022. Given the decommissioning of the reactor compartments and a relatively large amount of metal waste requiring melting, the next larger amount of metal must be probably melted from 2045–2050. Henceforth, melting takes place by one sea container (30 m^3) and considering the foreseeable generated metal waste streams in the future, the interval of melting is 60 years.

14.4. *Inventory*

The amount of existing radioactive waste in Estonia is estimated to be 1,950 m^3. The waste is located in the main building of the former nuclear submarine training centre in Paldiski, which is maintained by A.L.A.R.A. AS. Existing waste also cover the waste removed from Tammiku radioactive waste storage and transported to Paldiski site for further management from 2008–2011.

Since the preserved reactor compartments in the main building have not still been demolished, the waste amount generated in the course of their demolition has been estimated to be 900–1,000 m^3 in the study carried out in 2001 and based on the 50-year strategy for the storage of sections. As at 31 December 2013, the estimated activity of the reactor compartments was 169 TBq.

Existing waste packagings are located in the main building in the interim storage and control area. The waste is stored in metal and concrete containers (external dimensions 1.2 x 1.2 x 1.2 m), in full and half high sea containers, and in 200 l barrels.

While selecting suitable options for further waste management or interim storage / final disposal, it is necessary to know the isotopes and their activity in the waste, meaning that the waste must be characterised. Since existing waste in Estonia is mainly of historic origin and existing information on waste is still insufficient, it can be said that the majority of existing waste still requires characterisation. Currently, approximately 2.6 % of the volume of waste has been characterised. It mostly consists of sealed radiation sources received from other institutions and undertakings.

Since a large part of the activity of waste to be stored is mainly located in sealed sources, which has been transferred to A.L.A.R.A. AS along with detailed documentation, it can be estimated that together with the waste originating from the reactor compartments, approximately 40 % of the total activity of waste has been characterised. As at 31 December 2013, the activity of the characterised waste was approximately 730 TBq.

In particular, low- and very low-level waste need to be characterised, since its proportion of volume is high compared to other waste. These are particularly contaminated metal, contaminated concrete fracture, contaminated soft waste, and low-level concreted waste.

More detailed information about different types of waste and amounts has been provided in Chapter 5.

The waste located in the site of Paldiski is low- and intermediate-level radioactive waste, which is usually stored in either a ground-level final disposal site (established either on the ground or a few meters below the ground) or in an underground final disposal site (usually a tunnel located up to 100 metres below the ground). The appropriate solution for Estonia will be determined in the course of the preliminary studies of the establishment of the final disposal site carried out from 2014–2015.

In the future, the flows of radioactive waste generated in Estonia are very small and generally described in great detail. Significant amounts originate from the decommissioning works of Tammiku radioactive waste storage facility, i.e. contaminated concrete fracture generated during the cleaning of surfaces from pollution (approximately 28 m^3), and about 200 tonnes of potentially contaminated metal from Molycorp Silmet AS (if the factory plans to modernise the installation). Predictable stream of metal waste received from other establishments and undertakings will be approximately 0.5 m^3 of waste in a year in the future. Additionally, it is worth mentioning the NORM production residues of Molycorp Silmet AS in the amount of 72 t/y, however, according to the radiation practice licence issued in 2014, Molycorp Silmet AS will export it to the parent undertaking, where it is recovered as secondary raw material.

Short-lived nuclides, which are used in medical institutions, decompose below the clearance levels in a very quick manner (minutes, hours) and this process usually takes place already inside the patient, and then, these isotopes is channelled. Slightly longer-lived nuclides (days) are collected in a separate container and released after the decomposition of the nuclides below the clearance levels.

The volume of the sealed radiation sources that will be given to A.L.A.R.A. AS by other establishments and undertakings is 0.1 m^3 in a year. The rest of the waste flows and their activity, including orphan sources, are insignificant.

No significant development is expected in terms of waste clearance until waste is characterised. This will start in 2018. Currently characterised waste includes specifically the sealed sources of ^{90}Sr, ^{60}Co and ^{137}Cs, which have a high level of activity. Their radioactive decay below the clearance levels typically takes 100–1,000 years and therefore, it is appropriate to take this waste to the place of final disposal

14.5. Conscepts or plans and technical solutions from generation to disposal

When speaking about the technical solutions of waste management, it should be noted that the existing and future amounts of waste generated in Estonia compared to countries using nuclear energy are so small that the price of the majority of the new technological solutions per one unit of waste is significantly higher than in countries using nuclear energy. Additionally, the capacity of the devices is so high, that in most cases, it is possible to handle the waste amounts of Estonia within a week or a month. In such a situation, it is not practical to acquire new technology but, if possible, one should focus on the effective implementation of existing technologies and, where appropriate, seek for particularly mobile (rentable) waste management solutions (super-press, hot cell). The selection of a suitable technology and its later implementation should by all means take into account that in addition to the waste in the waste packaging, the decommissioning of the reactor compartments generate at least as much waste as there is now. This may change the use of some new technological solution in a more perspective way.

The most inexpensive, accessible, and suitable conditioning technology that applies to a majority of the existing and future amounts of waste generated in Estonia is concreting. In most cases, concreting is the final stage of waste management before storage. However, more work needs to be done before, starting with the characterisation of waste and ending with the preparation of compliance indicators of the waste packaging of the place of final disposal.

Since the volume of a very large part of the waste has been partially or completely uncharacterised, A.L.A.R.A. AS makes preparations for obtaining the gamma spectrometry device. Its purchase is scheduled for 2015. Gamma spectrometry is a suitable method to start the characterisation of waste while taking into account the activity and isotopes of the existing waste, the physical shape of waste packaging, the experience of staff, and the cost of method. The acquisition of equipment is followed by staff training on the use of equipment and measuring techniques will be prepared and tested for the assessment of waste packaging with different configuration and of the activity of radioactive waste still not packaged, including the assessment of measurement uncertainty, with the aim of a subsequent clearance of waste or final disposal. After the preparation of the waste clearance methods, the gammaspectrometric characterisation of waste should start in 2018.

From the selection of mobile rentable management solutions, Estonia is particularly interested in machine press and a special shielded chamber, or hot cell. Another option is to take waste to a foreign country to be handled (incinerator, super-press) and bring back already handled waste and carry out conditioning (concreting) in Estonia. Prior to final decision, it is needed to carry out an economic analysis – this, however, requires the preparation of compliance indicators of the waste packaging of the place of final disposal.

Table 8 shows the possible solutions for waste management, including interim storage and clearance or final disposal, of waste generated or to be generated in Estonia by type.

Table 8. The possible solutions for waste management, including interim storage and clearance or final disposal, of waste generated or to be generated in Estonia by type

Type of waste	Waste packaging	Waste origin	Type of waste	The need for characterisation	Possibility of clearance	Suitable treatment method	Alternative treatment method	Storage method
Low and intermediate level waste <30 y	Reactor compartment No. 1	Paldiski	revealed during preliminary studies	yes	revealed during preliminary studies	revealed during preliminary studies	revealed during preliminary studies	interim storage / final disposal
	Reactor compartment No. 2	Paldiski	revealed during preliminary studies	yes	revealed during preliminary studies	revealed during preliminary studies	revealed during preliminary studies	interim storage / final disposal
	Metal containers	Paldiski	concreted	yes	yes/no	handled	-	interim storage / final disposal
	Concrete containers	Paldiski	concreted	yes	yes/no	handled	-	interim storage / final disposal
		Tammiku	concreted	yes	yes/no	handled	-	interim storage / final disposal
		Estonia	sealed sources	no	yes/no	dismantling, placing into a collector container used as an additional shielding and concreting	concreting	interim storage / final disposal
	Sea containers	Paldiski	metal	yes	yes	melting	concreting	final disposal
			concrete fracture	yes	yes/no	concreting	-	interim storage / final disposal
	200 l barrel	Paldiski and Tammiku	compressible	yes	yes/no	pressing and concreting	concreting	interim storage / final disposal
			wood	yes	yes/no	incineration	waiting for the fall of the activity below the clearance levels	interim storage / final disposal
			metal	yes	yes/no	melting	concreting	interim storage / final disposal

Type of waste	Waste packaging	Waste origin	Type of waste	The need for characterisation	Possibility of clearance	Suitable treatment method	Alternative treatment method	Storage method
			concreted	yes	yes/no	managed	-	interim storage / final disposal
			stainless steel scrap, dust	yes	yes/no	concreting	-	interim storage / final disposal
	Liquid waste	Tammiku	organic liquid	yes	yes	incineration	chemical treatment	-
	Bulky waste	Paldiski	metal	yes	yes/no	cutting-up	-	interim storage / final disposal
	Waste generated in medical institutions	Estonia	chemicals	no	yes	waiting for the fall of the activity below the clearance levels	-	-
Low and intermediate level waste >30 y	Reactor compartment No. 1	Paldiski	revealed during preliminary studies	yes	revealed during preliminary studies	revealed during preliminary studies	revealed during preliminary studies	interim storage / final disposal
	Reactor compartment No. 2	Paldiski	revealed during preliminary studies	yes	revealed during preliminary studies	revealed during preliminary studies	revealed during preliminary studies	interim storage / final disposal
	200 l barrel	Paldiski and Tammiku	alpha-contaminated compressible	yes	no	pressing and concreting	concreting	final disposal
			alpha-contaminated metal	yes	no	melting	concreting	final disposal
			alpha-contaminated wood	yes	no	incineration	-	final disposal
			^{226}Ra indicators	yes	no	interim storage in an airtight container until the development of a suitable final disposal packaging	-	final disposal
NORM	Concrete container	Estonia	ground	yes	no	concreting	storage at NORM place of storage	final disposal

Type of waste	Waste packaging	Waste origin	Type of waste	The need for characterisation	Possibility of clearance	Suitable treatment method	Alternative treatment method	Storage method
			metal	yes	no	melting	storage at NORM place of storage	final disposal
	Sea container	Estonia	metal	yes	no	melting	storage at NORM place of storage	final disposal
	-	Molycorp Silmet AS	metal	yes	no	melting	storage at NORM place of storage	final disposal
	200 l barrel		production residues	no	no	export as secondary raw material	storage at NORM place of storage	-

14.6. *Cost assessment*

The cost estimate particularly highlights the higher known costs for obtaining equipment or ordering services. Higher costs for the characterisation, management and final disposal of waste are:

• The development of the waste characterisation system – up to 0.3 million euros for gamma spectrometry in 2015. This is followed by the acquisition of measuring devices enabling to determine alpha and beta radiation sources and staff training – up to 0.8 million euros from 2019–2029;

• the decommissioning of reactor compartments and the management of waste generated from them – preliminary analyses (also includes the establishment of the place of final disposal) 1.1 million euros from 2014–2015, the assessment of environmental impact (also includes the establishment of the place of final disposal) 5 million euros from 2017. This is followed by the application of necessary licences, the planning and construction of the place of final disposal (the place of final disposal should completed by 2040) and the dismantling of reactor compartments (starts in 2040). The estimated cost of the mentioned works must be determined by the preliminary studies that have already begun, therefore, it is not possible to state specific amounts at the moment. However, based on the experience of other countries, it can be spoken of approximately 90 million euros;

- the establishment of the place of final disposal – see previous point;
- the melting of contaminated metal – 2.51 million euros in 2018;
- the acquisition of a concrete knot to condition waste – 40,000 euros in 2020;
- The purchase of concrete containers for the final disposal of waste – 5 million euros from 2016–2040.

14.7. *Financing scheme*

Developed countries, which operate nuclear power stations, have special funds for the final disposal of generated waste and the financing of the commissioning of the stations that collect funds as a part of the price of the electricity sold. In case of institutional radioactive waste, the polluter pays principle is generally recognised, meaning that the waste owner is financially responsible for the management and storage of this waste.

Estonia is in a situation in which no waste management funds have been established due to a lack of nuclear power plants. Additionally, a total of 94.5 % of existing waste is of historic origin (sites of Paldiski and Tammiku) and the proportion in the future waste amount increases over 99 %, since waste streams that will arise from the source holders (institutional waste) are small. In such a situation, it is not reasonable to establish a management fund, since the resources collected there are virtually non-existent and inadequate to solve the problems of waste.

Estonia has implemented the system of financial securities, ensuring that the resources needed for the safe inclusion of used radiation sources are available. Pursuant to § 18^1 of the Radiation Act, upon applying for the radiation practice licence, the holder of the source shall be obliged to submit an assessment on the safe inclusion of the source, which is prepared by the radioactive waste handler. Then, the Environmental Board considers the economic credibility of the applicant and, where applicable, the amount required to the safe inclusion of the source will be deposited in the bank. The estimation of the cost of the safe inclusion of the source prepared by A.L.A.R.A. AS is based on a price methodology, which also takes into account the cost of taking waste to the place of final disposal. Since the new version of the Radiation Protection Act came into force on 10 November 2011, such a system has been implemented only in the last three years. Such an arrangement ensures that in case a company goes bankrupt, the state does not have to ensure safe inclusion from its resources. On the other hand, the proportion of such sources is small and this solution does not ensure the funding of final disposal, but rather reduces public expenditure to a very small extent and ensures the equal treatment of the holders of radiation practice licence.

Paldiski and Tammiku sites are state-owned and belong under the area of government of the Ministry of Economic Affairs and Communications (Paldiski site) and the Ministry of the Environment (Tammiku site). The Ministry of Economic Affairs and Communications orders services from A.L.A.R.A. AS to maintain and decommission the sites. In order to finance the services, the funds of the budgetary grant are used in the amount of approximately 0.45 million euros in a year. Additionally, A.L.A.R.A. AS provides the safe inclusion of orphan sources and preparedness assurance service, which is financed by the funds of budgetary support (preparedness) and the EIC (safe inclusion) in the amount of approximately 35,000 euros in a year. These funds are sufficient for the maintenance, decommissioning, and safe inclusion of orphan sources of the sites, however, these are insufficient to finance large-scale projects planned in the coming years, such as the decommissioning of the reactor compartments and the establishment of the final disposal site, the development of the characterisation and clearance systems of radioactive waste (see the implementation plan of 2012–2015 of the national development plan on radiation safety 2008–2017).

From additional public funding mechanisms, the EIC (www.kik.ee) is the most appropriate establishment for the financing of waste management projects. The EIC was established as a foundation on the basis of the Act on the Funds Received from Environmental Use and its amending Act in the area of government of the Ministry of Finance in May 2000. It main activity is to finance various environmental projects from the funds received from the Estonian environmental charges, the European Union Cohesion Fund (CF), the European Regional Development Fund (ERDF), and the European Social Fund (EFS) and to implement green investment scheme (CO_2 sales quotas and mediating subsidies).

One of the drawbacks of the EIC is definitely high-level competition in receiving the grant, since there are quite a lot of environmental areas of concern in Estonia. Therefore, all issues should be addressed on a project basis, and thus ensure their financing.

It is also possible to apply for support from the European Union Structural Funds to carry out projects. The grants of the programming period of 2007–2013 start to end and therefore, the funds of the programming period of 2014–2020 will be discussed further on. So far, the Structural Funds have supported projects to the extent of up to 85 %.

In addition to the EIC and the EU Structural Funds, another possible donor of waste management projects is the International Atomic Energy Agency (IAEA). Although the IAEA does not provide direct financial support, it offers expert assessments and organises expert missions in the country of location. The missions particularly represent an analysis of the situation and making decisions on the basis of available information, as well as highlighting possible weaknesses. Therefore, the possible support of the IAEA is rather analytical than material.

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- European Council Directive 2003/122/EURATOM of 22 December 2003 on the control of high-activity sealed radioactive sources and orphan sources.

Annex 1. General principles of radioactive waste management

Basic principles for radioactive waste management

Basic principles for radioactive waste management that have been established by the IAEA are the following:

- radioactive waste is managed in a manner that ensures the protection of human health and the environment to an acceptable level;
- radioactive waste is managed in a manner, which ensures that potential cross-border effects are taken into account with regard to human health and the environment of the neighbouring countries;
- radioactive waste is managed in a manner that does not cause an excessive burden on future generations, and with predictable effects on human health that would not be greater than today's acceptable level;
- radioactive waste is handled pursuant to the provisions of the legislation. Legislation must, inter alia, ensure the existence of an independent regulatory authority and a clear division of areas of responsibility;
- the generation volumes of radioactive waste are kept as low as possible;
- while generating and managing radioactive waste, any interdependence between the generation of radioactive waste and the stages of its management should be taken into account;
- the safety of the waste treatment facility is ensured throughout their lifetime.

These fundamental principles are, one way or another, also reflected in the Estonian legislation. In the Republic of Estonia, the principles for the radioactive waste management and the obligations related to management are established in the Radiation Act. Among other things, it provides that the radiation practice licence holder must guarantee the safe management of radioactive waste and emissions generated during radiation practice and ensure that:

- radioactive waste is managed in such a way that the estimated harmful effect on future generations would not be higher than permitted by the Radiation Act or legislation provided on the basis of this Act;
- the activity and amounts of the generated radioactive waste and emissions would be as small as possible;
- biological, chemical, and other dangers, as well as interaction between the stages of radioactive waste generation and its management would have taken into account;
- the transfer of radioactive waste to the radioactive waste management site would not take place later than within five years after their generation;
- the holder of the radiation practice licence, which has been issued for radioactive waste management, ensures that the safety of radioactive waste management site would be guaranteed throughout the period of use;
- the generator of radioactive waste must cover all costs related to the radioactive waste management.

Radioactive waste management techniques

Based on the recommendation of the IAEA, radioactive waste is managed by using methods known from the practice of non-hazardous waste management, such as concentration and isolation, as well as dilution and separation, and unique procedures, such as delay and radioactive decay.

The selection of procedures is particularly based on the amount of radioactive waste and its special activity. In the event of radioactive waste in smaller amounts and with higher special activity, it is often preferred to use concentration and isolation. In the event of larger amounts and smaller special activity, particularly dilution and dispersion are considered. However, in addition to above-mentioned general principles, radiation-related legislation also includes more specific provisions:

- different type of radioactive waste with different physio-chemical properties must be separately collected and stored;
- untreated radioactive waste must be collected and stored separately from conditioned waste;
- radioactive waste must be collected and stored separately from caustic, explosive and inflammable substances;
- biological radioactive waste must be collected and stored in a frozen state, placed in an appropriate solvent, or processed in some other appropriate manner;
- used sealed radiation sources must be collected and stored either in their own or any other suitable radiation shielding shell;
- sharp radioactive waste must be collected and stored separately, preferably in a metal container, which has been labelled as "Sharp radioactive objects";
- unconditioned wet solid radioactive waste must be collected and stored in at least a double storage container in order to prevent the leakage of radioactively contaminated liquids;
- unconditioned liquid radioactive waste must be collected and stored in a container, which is surrounded by an absorbent material in an amount that ensures twice as high binding of the amount of liquid than that of the liquid in the container. The container may be placed inside of another container or reinforce it in some other appropriate manner.

When speaking about radioactive waste management, it is very important in the first stage to ensure the minimisation of the amounts of waste to be handled. In terms of the minimisation of waste streams, the general principles of waste management can be formulated as follows:

- to keep the amount of generated waste as low as it is possible when taking various factors into account;
- to keep the spread of radioactive contamination under control during radiation activities in order to reduce the possibility that as a result of contamination, the amount of radioactive waste that needs to be managed would increase;
- to optimise the opportunities for processing and recycling of components;
- the implementation of management techniques to minimise the amounts of waste.

The aim of minimising the waste amount is to decrease the amount of generated and managed radioactive waste and reduce the spread of pollution. The objective of the overall activity is to ensure that the amount of managed radioactive waste (including waste to be taken to the place of final disposal) would be minimum. The main activities related to the minimising of waste may be divided into four subgroups:

- reducing sources of radioactive waste;
- preventing/controlling the pollution of materials;
- processing and recycling of materials;
- optimising the radioactive waste management.

It possible to use various tools and techniques to control the generation of radioactive waste. In Estonia, the Radiation Act provides the basic principles of radiation safety based on which the planned activities must be justified and proven in advance that this is the best possible solution when considering economic, social, and other aspects. This means that if the radiation practice licence applicant or licence issuer finds that the planned radiation activity still has a better alternative, the radiation practice licence will not be issued for this activity. The implementation of the general principle keeps the amounts of generated radioactive waste as small as it is possible when considering various aspects.

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management establishes that if the safety of management enables it, then radioactive waste should be taken to the final disposal site in a country in which they have been generated. On the other hand, international radiation practice contributes to returning the used radiation sources to the manufacturer.

In general, it is possible to use several option to ensure the reduction of the amount of radioactive waste – starting with work culture and ending with different technological solutions. In the context of the reduction of the amount of waste, it is important to ensure clearly established division of responsibility and work tasks. The latter applies both to such an activity in the course of which radioactive waste is generated, as well as the activities of the waste handlers. Important parts of work culture are, inter alia, work procedures, which form a part of the quality system of radiation safety, the development of used techniques, the renewal of technologies, etc. Also, staff training and their awareness-building should not be underestimated. It is possible to decrease the waste to be generated by cleaning tools and materials that have been contaminated in the course of various activities. The selection of methods should always also consider economic, social, and environmental aspects, namely to assess the economic viability of the activities, taking into account the impact on humans and the environment. The control mechanisms can be divided into administrative and technical.

Administrative control mechanisms:

- continuous renewal of technical data and conversation measures;
- the organisational structure to ensure a clear division of responsibility;
- regular inventory of radiation sources and radioactive waste;
- the preparation of work processes also considers activities during which radioactive contamination may occur;
- the continuous development of operational procedures and the exchange of experiences;
- the regular training of radioactive waste handlers and the exchange of experience.
- Technical factors, which may contribute to the minimisation or prevention of the generation of radioactive waste:
- the design of the establishment;
- the choice of materials;

- the use of the establishment and systems;
- cleanliness and the clearance of contamination.

In order to gain an overview of the implementation of administrative and technical factors, the radiation practice licence applicant must submit an overview of ensuring radiation safety, radiation work rules, and the description of the quality system of radiation safety in addition to the application materials.

Once radioactive waste has been generated, it is necessary to minimise the volume of handled waste in order to reduce the cost of their management. Naturally, the principle of optimisation should be monitored at the reduction of volumes, in other words, it is necessary to also take into account the cost of processes and to find the most optimal solution. Different countries use different methods for reducing the volumes of radioactive waste. These methods are mainly based on mechanical, physical, chemical, biological or thermal processes and the most suitable one is selected in a way that takes into account the properties of the generated radioactive waste and their volumes.

One aspect to be always considered it that it is possible to regulate and control the generated amounts of waste by means of recovery of materials. It is also important to separate different types of waste in order to reduce the amounts of generated waste and facilitate their management. The management of mixed waste is generally much more expensive and complicated than the management of separated waste.

Types of radioactive waste

Pursuant to international practices and also the Estonian legislation, radioactive waste is classified according to the following properties of the radionuclides contained therein:

- activity and specific activity;
- half-life;
- type of radiation;
- amount of heat arising from the radioactive decay.

Estonia has established the following types of radioactive waste:

- “Cleared waste” – waste generated during the radiation practices with its activity, specific activity or surface-specific activity being smaller than the established clearance levels. These types of waste may be handled the same way as regular waste after their clearance;
- “NORM waste” – radioactive waste generated as a result of the processing of raw material containing natural radionuclides (Th-232 and U-238, as well as radionuclides belonging to their decay series) with its specific activity being higher than the established clearance levels; NORM waste place of final disposal is needed for storage.
- “Short-lived radioactive waste” – radioactive waste containing less than 100-day half-life radionuclides, such as iridium-192 with its half-life being 74 days, and decomposing below the clearance levels for up to five years. A storage facility or interim storage of radioactive waste is needed for storage;
- “Short-lived low- and intermediate-level radioactive waste” – radioactive waste containing less than 30-year half-life beta and gamma emitters, such as cobalt-60, and a limited amount of long-lived alpha emitters, such as radium needles (not more than 4,000 Bq/g in one waste packaging and not more than an average of 400 Bq/g per total amount of waste). Interim or final place of storage needed for storage;

- “Long-lived low- and intermediate level radioactive waste” – radioactive waste containing greater than 30-year half-life radionuclides with their specific activity being higher than that of short-lived low- and intermediate radioactive waste and for which the amount of heat generated by the radioactive decay is less than 2 kW/m^3. Interim or final place of storage needed for storage;
- “High-level radioactive waste” – radioactive waste for which the amount of heat generated by the radioactive decay is greater than 2 kW/m^3, such as for spent fuel. Final place of storage is needed for storage.

Types of radioactive waste generated in Estonia from their generation to final disposal or clearance have been provided in the following figures:

Figure 1 shows the movement of short-lived low- and intermediate-level waste, Figure 2 shows the movement of long-lived low- and intermediate-level waste, and Figure 3 shows the movement of NORM waste from their generation to their final disposal or clearance.

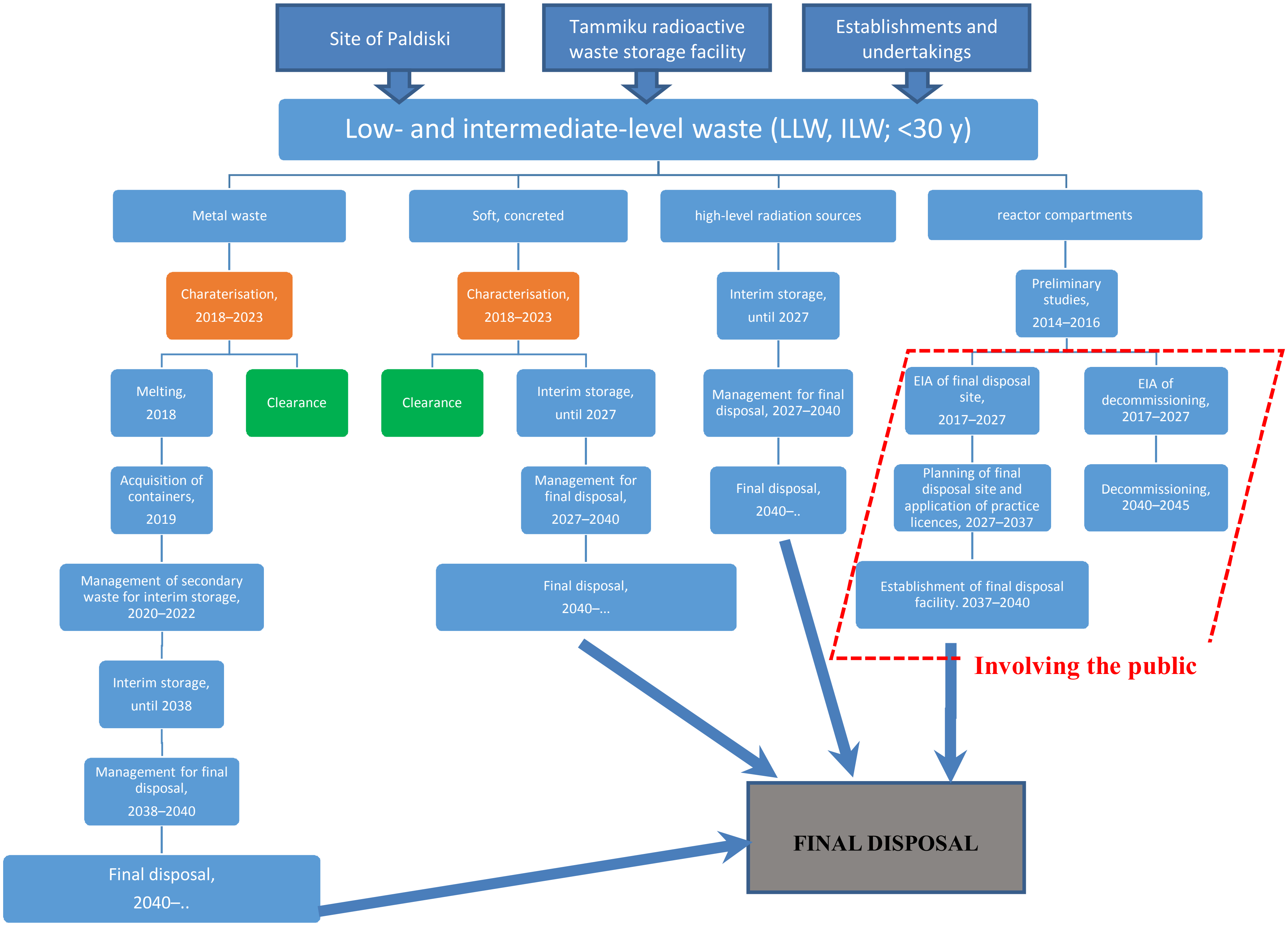

Figure 1. The movement of short-lived low- and intermediate-level waste from its generation to its final disposal or clearance.

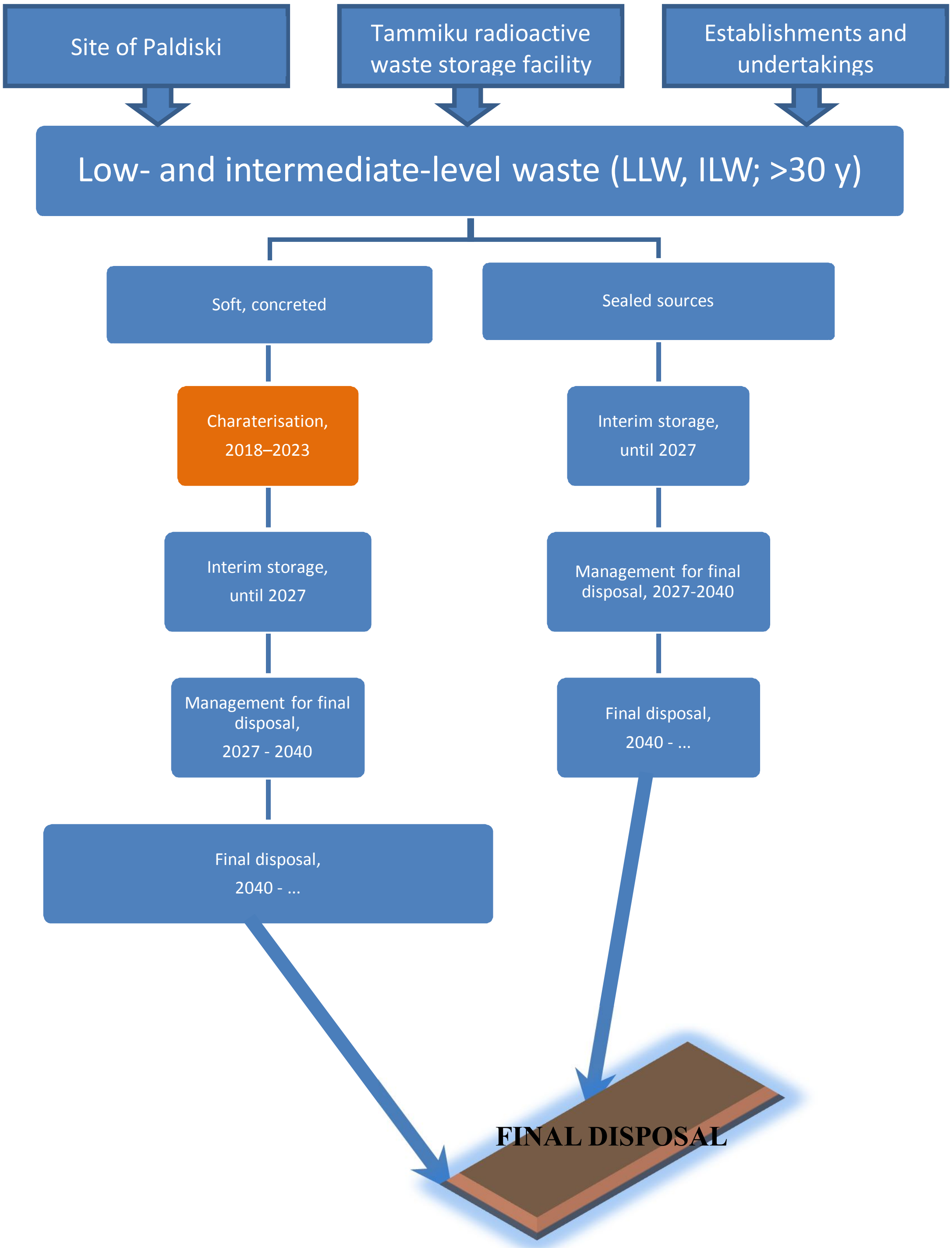

Figure 2. The movement of long-lived low- and intermediate-level waste from its generation to its final disposal or clearance.

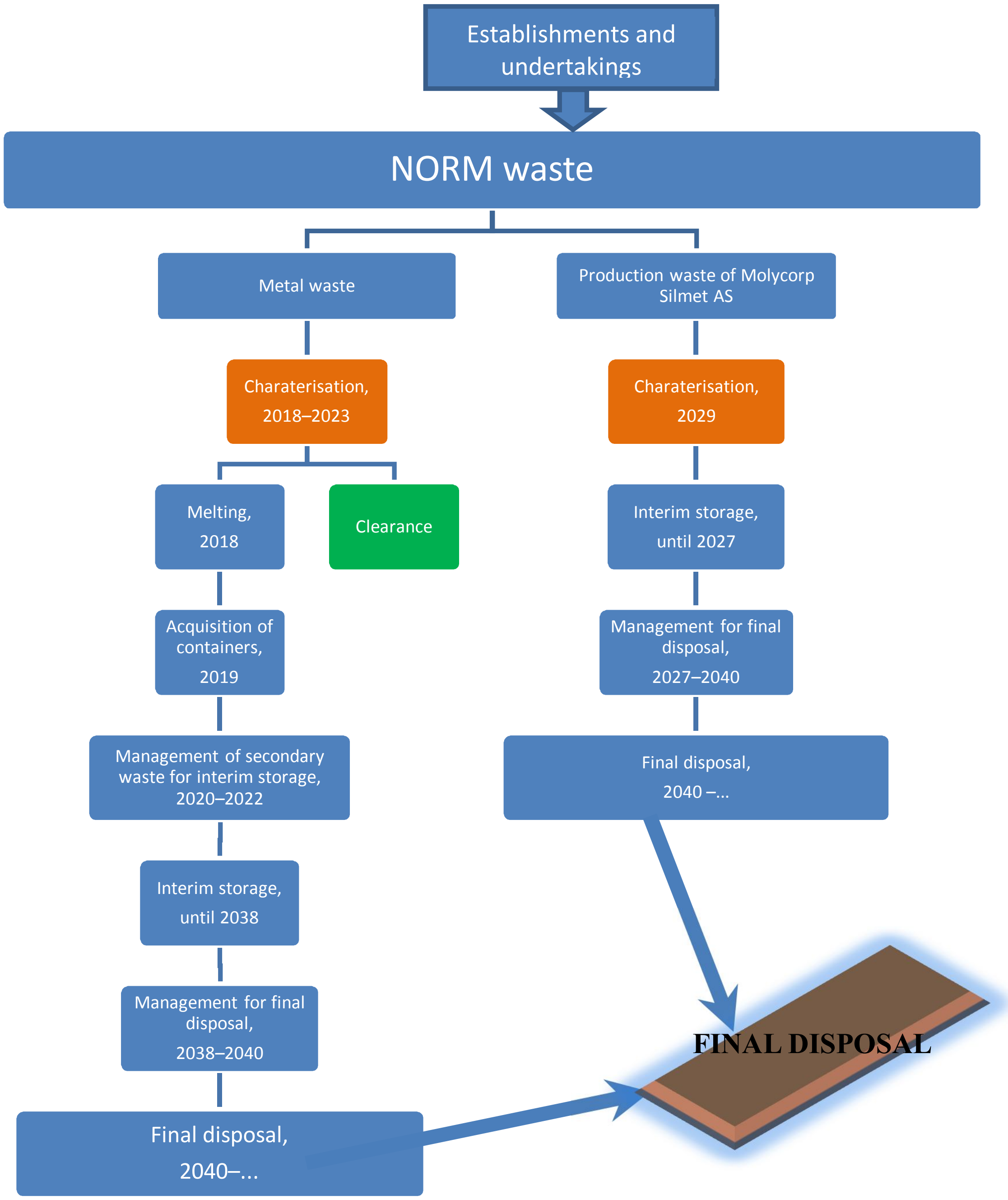

Figure 3. The movement of NORM waste from its generation to its final disposal or clearance.