PRELIMINARY STUDIES FOR THE DECOMMISSIONING OF THE REACTOR COMPARTMENTS OF THE FORMER PALDISKI MILITARY NUCLEAR SITE AND FOR THE ESTABLISHMENT OF A RADIOACTIVE WASTE REPOSITORY

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1. INTRODUCTION

When the Republic of Estonia regained independence in 1991, it inherited two military-purpose training reactors, similar to the reactors used on nuclear submarines which were installed at the Navy training centre in the Northern part of Pakri Peninsula for training of submarine crews of the Northern and Pacific Fleets of the then Soviet Union with an aim to provide training to mariners in as realistic conditions as possible prior to their assignment to submarines.

Nuclear reactor No. 1 (PWR/VM-A-type reactor with a thermal output of 70 MW) commissioned in April 1968 was used until January 1989. It was emplaced in a metal housing similar in shape and dimensions to a nuclear submarine. The reactor was refuelled in 1980, and its total operating time (at 20-40% load) was 20,821 hours (13,781 hours with original fuel and 7,040 hours after refuelling).

Reactor No. 2 was a PWR/BM-4 (LWR)-type reactor with thermal output of 90 MW. Commissioned in February 1983, it was used until December 1989 at a load of approximately 30% without refuelling. The total operating time of reactor No. 2 was 5,333 hours.

The decision to safely shut down the training centre on the Paldiski site was made in 1991, after recognition of Estonia’s independence by Russia and withdrawal of the Russian troops from the region. Until 1995, Russian authorities performed the following works in order to ensure long-term safety of the reactor compartments:

- defueling of the reactors and transportation of the fuel to Russia;
- disassembly of auxiliary compartments;
- removal of non-radioactive equipment;
- draining of liquids from the primary circuits and sealing of the reactors;
- draining of cooling water purification filters;

- removal of non-radioactive equipment located above the biological protective layer (water jacket around the reactor for capturing of neutrons);
- reinforcement of the support structures of the reactor compartments;
- construction of reinforced concrete sarcophagi and grouting of various radioactive units and accesses inside the reactor compartments.

Pursuant to the agreement concluded between the Russian Federation and the Republic of Estonia (30 July 1994), the training centre together with the training reactors and the nuclear waste storage facility building was transferred to the ownership of the Republic of Estonia on 26 September 1995.

In 1995-2011, extensive conservation, cleaning and reconstruction works were carried out at the Paldiski site of the former military area, as the site contained large amounts of radioactive and non-radioactive residual contamination which posed a threat to surface, ground water and soil. Among other things, various buildings were cleaned and demolished and an interim storage facility for radioactive waste was installed in the main building.

As a result of the 1999-2001 European Union (EU) project, the *Evaluation of Management Routes for the Paldiski Sarcophagi*, the project expert committee found that from the point of view of radiation safety and waste storage, it would be expedient to commence the final decommissioning (decontamination and full dismantling) of the reactor compartments that form the main source of residual contamination at the site after 50 years of storage, i.e. around 2040.

In the course of the 2005-2008 EU PHARE project, the *Safe Long-term Storage of the Paldiski Sarcophagi & Related Dismantling Activities*, storage conditions were improved by installing an air drying system in the sarcophagi for the purpose of increasing corrosion resistance, a monitoring system was installed on the reactor compartments for the purpose of detecting possible spills and the main building surrounding the reactors was renovated, thereby making it more weather-proof.

The decision of the expert committee for the *Evaluation of Management Routes for the Paldiski Sarcophagi* project was based on the assumption that the radioactive waste to be generated in the course of the decommissioning of the reactor compartments commencing in 2040 will be deposited in a radioactive waste repository established by that time at the latest. The interim storage facility established in 1997 has been designed to accommodate all of the radioactive waste generated in Estonia (including the radioactive waste generated in the course of decommissioning of the nuclear submarine crew training centre at Paldiski and the waste removed from the Tammiku radioactive waste storage facility), except for the waste generated in the decommissioning of the reactor compartments. Therefore the environmental, technical and other analyses and studies relevant to the establishment of the repository must be started simultaneously with the environmental, technical and other analyses and studies necessary for the decommissioning of the reactor compartments because the results of one activity form an input for the other activity and vice versa. The aim of the present project is therefore to carry out preliminary technical studies and collection data required to provide a basis for planning of further activities, decision making and commencement environmental impact assessments.

The output of the present project will create the conditions necessary for starting of the environmental impact assessments of the decommissioning of the reactor compartments and serve as input for the design of a radioactive waste repository. After the environmental impact assessments, the design and construction works of the repository and the decommissioning of the reactor compartments can commence.

To reach the goals of the present project Contract No.33 / EKS0101-09 has been signed on 17 September 2014 between AS A.L.A.R.A. and UAB EKSORTUS *Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository.*

2. EXECUTIVE SUMMARY

Contract No. 33/EKS0101-09 between AS A.L.A.R.A. (hereafter the Client) and UAB EKSORTUS (hereafter the Contractor) for implementation of Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository project was signed As a result of open tender procedure (basis: Division 6 of the Public Procurement Act (PPA)) on 17 September 2014. Effective date of the Contract is 17 September 2014. Date of the Project completion: 30 December 2015.

The source of financing of the Project: measure “*Elimination of residual pollution in former military and industrial areas*” under the European Union structural funds for the period of 2007-2013.

The contract was implemented by a consortium of “UAB EKSORTUS – Research and Development Company SOSNY”.

EKSORTUS (Lithuania) is a private engineering company. The company’s main activity is implementation of projects related to decommissioning of nuclear facilities including turn-key projects.

The Research and Development Company SOSNY specializes in the developments and research in the field of nuclear power engineering. The Sosny Company undertakes non-standard tasks of handling spent nuclear fuel from power, research and propulsion reactors in Russia and abroad.

In order to support the consortium in implementation of tasks 2, 3 and 5 the Contractor subcontracted the **Federal Centre for Nuclear and Radiation Safety** (Russian Federation) which is a corporate member of the State Atomic Energy Corporation ROSATOM.

For the support of the consortium in implementing task 4 the Contractor subcontracted **Specialus Montažas – NTP** (Lithuania) for its broad experience in successful implementation of multi-purpose international projects related to decommissioning of NPPs and radioactive waste management.

The main task-by-task assumptions and conclusions are presented below.

TASK 1
ORGANIZATIONAL PROJECT ACTIVITIES

The task was dedicated to project management, planning and reporting activities. Also, this task establishes the framework for project implementation. In the course of the Project implementation the Contractor organized 4 seminars:

- Introductory seminar
- Technical seminar No 1 dedicated to the decommissioning of reactor compartments
- Technical seminar No 2 dedicated to radioactive waste disposal
- Final seminar dedicated to Project results

The Contractor also prepared a Final Report covering all the six Tasks listed in the technical specifications of the project in English and Estonian languages.

TASK 2
COLLECTION OF DATA AND OVERVIEW OF NATIONAL AND INTERNATIONAL REQUIREMENTS

1. Assessment and evaluations, based on calculations and additional data inputs during the implementation of Task 2 "*Data Collection and Review*" of the Contract on performance of current Project has led to a number of findings. The procedure of collection and assessment of the input data to accomplish Task 2 included:

- firstly, obtaining the available documents, reports, explanatory notes, information containing investigation results, measurements of the present parameters of the facility and the two reactor compartments from A.L.A.R.A. AS;

- secondly, usage of the experience, knowledge and expertise possessed by the professionals of the General Project Engineering Group, who designed the Naval training centre in the City of Paldiski, namely Atomproekt JSC;

- thirdly, technical visits made by the engineers of Eksortus, FCNRS JSC, Atomproekt JSC to the Paldiski site with a view to inspect the condition of the site, buildings, grouted reactor compartments of Units 346A and 346B, adjacent premises as well as premises for intermediate storage of radioactive waste containers. During the visits, the engineers were briefed in detail on the history of the training centre, including its aims and tasks, the background information relevant to the operation of the nuclear-powered submarine reactor prototypes, key performance characteristics of the reactor plants, their operating periods, the decision on decommissioning and selection of the deferred decision concept, the time frame for moth-balling of the reactor compartments, the work done on the site and in the building of the reactor compartments for the purpose of improving safety. The engineers were also familiarized with the main process equipment available in the building where the reactor compartments are located, including control, measurement and monitoring instrumentation;

- fourthly, organization of technical and steering committee meetings. During two steering committee meetings the Customer's representatives gave a detailed presentation of the aims and tasks of the preliminary investigation. At the same time, the Contractor made a presentation of their vision for achieving the aims and tasks of the preliminary investigations as well as results expected. The Contractor presented the results of the investigations obtained, which were commented on in detail by the representatives of the Customer.

The procedure of transmitting the input data from the Customer was carried out on the basis of the Contract provisions. The Contractor executed appropriate authorizations to transfer the information to the Customer, including the information to be accounted for, in due course, on the basis of the Contractual obligations. No confidential information, or limited disclosure information or classified information was used in the course of the present investigations.

Despite a number of limitations, the present report incorporates all the available information collected and the input data as of the middle of 2015.

2. For the purpose of conducting the investigation and on the basis of the collected information, a list of the available documents, investigation materials, radioactive checkouts, operational history, safety reports, and reports on environmental impact assessment was made. The list is provided in the Reference section in Section 2.1 of Task 2 report.

3. Based on the experience, the requirements of the legislative and normative framework, a list of principal criteria for the decision on decommissioning of the two reactor compartments was established:

- political decision after the change in the status of the Republic of Estonia in 1992;
- assurance of safety for the personnel, population and environment;
- assurance of physical protection for the former training centre in the city of Paldiski;
- compliance with the requirements of the norms and regulations of the EU and IAEA

More than two decades have elapsed since work was done to immediately decommission the nuclear-powered submarine prototype units and to mothball the reactor compartments. Experience, condition of the building, its building structures, and concrete structures around the reactor blocks and control and monitoring data were used as the key criteria for the decision to be made regarding the dismantling of the mothballed reactor compartments or continuation of their controlled storage. The ageing of the facility will result in:

- reduced level of safety for the personnel engaged in control and monitoring of the condition of the reactor compartment site;
- negative impact of the site upon the city of Paldiski and neighbouring population and environment;
- increased cost of the work to be done in order to dismantle the reactor compartments;
- delayed decision at the level of the Government of the Republic of Estonia regarding the selection of disposal site for radioactive waste.

4. The results of acquiring available information regarding the condition of the reactor compartments, reactors and the process equipment as of the date of placing them in the storage mode according to design documentation, data as of 1995. Estimated data provided as a result of investigations carried out in 2001 have made it possible to confirm the design data, radiation characteristics and radionuclide composition of equipment in units 346A and 346B, including:

- technical characteristics and design of the systems of the main primary circuit: steam generators, main circulation pumps, pressure compensators, auxiliary circulation pumps, heat exchangers, reactor heat carrier cleaning filters;
- engineering drawings containing internal configuration of each component of the primary circuit from those enumerated above, path length, material thickness, final configuration at every side of each blanked component (pipe dimensions, elbow lengths, blank dimensions) and demonstrating the method of equipment attachment in the reactor compartments;
- complete piping data of the primary and secondary main circuits, which determine the path length, material types, thickness and weight;
- technical characteristics and design of the main equipment of the second, third and fourth circuits of the reactor heat carrier;
- radionuclide inventory given for every part of the plant as of 2015, 2039 (50 years after shutdown) and 100 years after shutdown which includes long- and short-lived radionuclides. The calculation of induced radioactivity in stationary premises of compartments 346A and 346B as well as induced radioactivity of the concrete used for grouting has been performed. The data has also been obtained by extrapolating results of the previous investigations;
- assessments of the radiation dosage rate as of 2015, 2039 (50 years after shutdown) and 100 years after shutdown in the reactor compartment 346 A and 346B starting with statistical data (i.e. preceding radiological cartography) and calculations using data on induced radioactivity and radionuclide inventory. The radiation dosage rate average values

have been provided for the main equipment of the first circuit (average radiation dosage rate as of 2015 and estimate for 50 and 100 years after shutdown).

5. Collected data is sufficient to develop options for reactor compartment decommissioning and assess the volume and radioactivity of the waste produced.

6. Conducted analysis and calculations of the existing waste located in the internal premises of the reactor compartments, quantity and the update thereof during reactor compartment dismantling have made it possible to refresh and update the information of the preceding investigations. The overall amount of the existing radioactive waste will equal 1949.2 m^3 according to the assessment made in 2015.
7. The conducted analysis related to the amount of radioactive waste to be generated by the future operation of one NPP unit with capacity up to 1,000 MW has shown that the amount of radioactive waste depends on the type of the reactor as well as radioactive waste generation from dismantling of one NPP unit.

The total amount of conditioned radioactive waste over the entire period of operation of one unit with AP-1000 reactor with the design operating time of 60 years would be approximately (at least) 9 324 m^3. The total amount of conditioned radioactive waste expected to be generated during operation and decommissioning of a power plant with an AP-1000 unit is (at least) 15 401.5 m^3.

8. The source data and the obtained results with respect to task 2 are reliable since they have been received from trustworthy sources. All calculations have been performed by specialists with relevant experience, certificates and licenses.

9. The analysis of the necessity for additional data and unaccounted factors (uncertainties) has been carried out in the course of evaluating demand for additional information for taking future decisions for subsequent works such as design, environment impact assessment procedure, etc. Such works will include fulfillment of the comprehensive engineering radiation safety audit (CERS) of the reactor compartment building, adjacent areas, premises and radioactive waste storage. A detailed description of the requirements and scope of investigations and studies has been prepared within the report. The data acquired in the course of CERS will be used as the basis for performing design works on reactor compartment dismantling, preparation of report on the environment impact assessment procedure and measures for environment protection. It is not reasonable to carry out the environment impact assessment procedure without conducting CERS.

10. The review of international and state recommendations and regulatory documents on the reactor compartment decommissioning has demonstrated a necessity for introduction of changes into the legislative and regulatory environment for nuclear reactors, which is described in detail within the present report.

11. The review of international and state recommendations and regulatory documents on the ultimate disposal has demonstrated a necessity for introduction of changes into the legislative and regulatory environment for nuclear reactors, which is described in detail within the present report.

12. The following options of the decommissioning concept for the former training centre in Paldiski have been considered for the purpose of these preliminary surveys:

Concepts A and B with full dismantling and cutting of equipment into large fragments to minimize dose exposure based on option A or into small fragments followed by decontamination to reduce the amount of radioactive waste generated based on option B. The reactors and reactor internals are not to be dismantled.

- Concepts C and D – reactor compartment disposal as a whole unit without dismantling either in existing sarcophagi or in a newly constructed radioactive waste storage facility.

Concepts C and D were excluded at the further stages of examination since they comply neither with existing requirements of European regulations nor with IAEA requirements.
Under Concept A access to equipment and devices is required for dismantling, which necessitates crushing the concrete; large-sized shielded casks are to be designed and manufactured to dispose of the large fragments generated.
Under Concept B dismantling and concrete crushing equipment is also required but in this case decontamination and waste reprocessing shall be widely used to reduce the amount of radioactive waste to be disposed of.

13. Estimated radioactive waste amounts generated from Paldiski reactor decommissioning are as follows:

Concept A – ILW and LLW radioactive waste 732 m^3, non-radioactive waste 2000 m^3;
Concept B – ILW and LLW radioactive waste 519 m^3, non-radioactive waste 2130 m^3;
Concepts C and D – ILW and LLW radioactive waste 1545 m^3, non-radioactive waste 1260 m^3.

Existing radioactive waste amount stored in the Paldiski site interim storage facility and in the control area is 985 m^3.
Anticipated annual radioactive waste stream in Estonia is about 0.85 m^3. As decommissioning and final disposal will start in 2039, it is expected that about 20 m^3 of radioactive waste will be generated over the period of 2016-2039.

Following investigations conducted during the development of task 2, it can be confirmed that the condition of preserved reactor compartments is safe and reliable and will be kept unchanged within the nearest decades to come.

The current report and its results are preliminary studies for the decommissioning of the reactor compartments and for the establishment of a radioactive waste repository. They provide an indicative assessment for the decision making and they should be clarified, updated and improved at the further stages of the preparation for the Paldiski reactor compartment decommissioning and development of a concept of the establishment of radioactive waste repository.

In order to maintain safety of the reactor compartments, it is necessary to provide continuous control and monitoring conditions of the reactor compartments, buildings, adjacent areas as well as maintenance and repair of the buildings and premises.

In case of adopting a decision on the beginning of works regarding final decommissioning of the former Navy training centre in Paldiski, first of all, it will be necessary to carry out an integrated engineering radiation safety survey and then develop design documentation and environment impact assessment procedure with the environment protection measures based on the acquired data.

It is very important to develop and put into effect the missing regulatory documents or append the existing legislative and regulatory documents for nuclear reactors prior to beginning the design works on decommissioning and construction of the final repository for radioactive waste. Detailed analysis of the legislative framework of the Republic of Estonia and needs for possible amendments are presented within Annex 1 of the present report "*Assessment of the Legislation of the Republic of Estonia*".

TASK 3
DETERMINING THE POSSIBILITIES OF DECOMMISSIONING THE REACTOR COMPARTMENTS

The following conclusions can be made based on the surveys and analyses developed to determine whether the reactor compartments of the former training centre in Paldiski can be decommissioned:

1. The analysis of various techniques used for decommissioning of the reactor compartments was carried out based on available data from decommissioning of nuclear submarines in France, the UK, the USA, Germany and the Russian Federation. Each country in possession of nuclear submarines has its own dismantling concepts or strategies. The principal solutions used in strategies of these countries are very similar in essence. The USA and the RF are most advanced in the dismantling because they have already dismantled a significant number of nuclear submarines within the scope of Intergovernmental agreements on threat reduction (more than 200 nuclear submarines according to some sources). There are no published data, however, on the dismantling of facilities similar to the former training centre in Paldiski. According to the concepts of the above countries, a nuclear submarine is to be dismantled one compartment after another, and the reactor compartment shall not be dismantled or segmented. A unit is to be made from one or two nuclear submarine reactor compartments. The unit shall be prepared for long-term storage and then transported to the storage site. At present, in all mentioned countries, there are specific long term storage sites to store reactor compartment units safely. The period of such reactor compartment storage in the RF is assumed to be about 70 years. The research is in progress to find solutions on the future of reactor compartments being stored. None of countries that own dismantled nuclear submarines has started the reactor compartment dismantling for their final disposal.

A similar concept on the accelerated decommissioning of units 346A and 346B was implemented at the Paldiski site. The reactor compartments were transferred to a safe state, some internal premises were grouted and then surrounded by concrete sarcophagi, with no access into internal parts. However, the monitoring of radiation situation, temperature and air humidity was ensured inside the reactor compartments and inside the buildings comprising the sarcophagi. **The task 2 report has confirmed that the sarcophagi are in a safe condition. The designed period of the sarcophagi storage is 50 years, ending in 2039.**

2. The analysis of reactor compartment decommissioning options revealed that concept B (full dismantling with cutting into small parts and disposal of the reactor compartment as a whole unit.) is the most labour-intensive. It requires state-of-the-art equipment to be available:

- to dismantle and cut reactor equipment;
- to crush concrete without damaging the items located inside the concrete;
- monitoring means allowing to 'see' foreign items inside the concrete;
- units for various types of decontamination;
- units to reprocess and condition radioactive waste generated.

Production infrastructure is also required to manufacture shielded casks (if prefabricated certified casks could not be purchased) designed to load and store generated radioactive waste after conditioning. It is required to ensure construction of an interim radioactive waste storage facility on-site to store casks loaded with radioactive waste before transportation to the disposal facility newly built in the Republic of Estonia for the disposal.

On the other hand, concept B allows reducing the amount of waste that requires final disposal and, if implemented, the capacity of the radioactive waste storage facility would be the least due to the smallest number and size of the casks required to dispose the whole volume of radioactive waste generated and handling of other non-hazardous components.

Total volume of conditioned radioactive waste arising from the decommissioning process according to concept B is about 987 m^3. About 650 m^3 of waste will be suitable for disposal in a subsurface intermediate depth type facility (reactors, shielding tanks - specific activity of more than 4000 Bq/g) and 337 m^3 will be disposed in a near-surface type facility (steam generators, pumps, etc.).

3. The Concept of the reactor compartment Decommissioning in Paldiski was developed based on the analysis of selected reactor compartment decommissioning options taking into account IAEA requirements and indicative assessment of performance characteristics. The reactor compartment condition and expected amount of waste were taken into account during development of the Concept. The Concept comprises the following sections:

- Definitions;
- Issue description and Concept objective;
- Concept application field;
- Normative legal base of the Concept;
- Main principles of the Concept;
- Technical and economic basis of the Concept;
- Principal solutions to implement reactor compartment decommissioning;
- Radiation safety and environmental protection;
- Conclusions.

4. The expert indicative assessment of concepts A and B (without cutting the reactor vessel) development was based on the following parameters:

- duration;
- cost;
- number of personnel and their qualification;
- usage of equipment, tools, and machinery;
- radiation exposure of Group A and B personnel;

The principle stages of decommissioning activities have shown that the most efficient concept for implementation is Concept B – cutting the building structures and equipment into small fragments.

5. An indicative schedule and sequence of works have been developed. Some works may be carried out in parallel. A number of works of the preliminary stage, described in the present report, are already in progress. The active part of works shall commence only after the decision has been made to proceed with final decommissioning and a license has been obtained. The duration of works shall be specified based on the design documentation after completion of a comprehensive engineering and radiological survey.

6. The following was determined during the surveys and analysis of concepts A and B:

- amount of all radioactive waste and its radionuclide composition, activity, types of waste and amount of each type of waste;
- recommendations to be given for the storage and disposal of waste taking into account the techniques for its reprocessing in order to minimize radioactive waste;
- number and types of casks for radioactive waste;
- amount of non-radioactive waste including toxic waste determining the toxicity class.

7. **The safety analysis developed for Concept B was based on respective criteria including assessment of risks during the works, potential risks in case of off-optimum situations or incidents with the assessment of potential consequences. Analysis shows that practical activities on reactor compartment decommissioning at Paldiski facility, using state-of-the-art equipment may be carried out sufficiently safely and the main safety principles can be fulfilled.**

The expert assessment of decommissioning activities was made during the analysis of the chosen reactor compartment decommissioning option. More detailed safety analysis of reactor compartment decommissioning activities shall be developed based on completed comprehensive engineering and radiological survey results and then at the stage of design documentation development.

When developing the safety analysis for the decommissioning the following was taken into account:
- most of radiation hazardous activities inside the reactor compartments may be carried out using remotely controlled equipment thus minimizing personnel exposure;
- however, there is a number of process operations that shall be implemented with direct participation of qualified personnel. Those processes include:

- all activities associated with the usage of oxygen acetylene cutting (including air plasma cutting), as well as welding;
- decontamination;
- process cleaning at working places;
- on-line radiation monitoring at working places.

It shall be noted that the most hazardous materials are spent neutron radiation sources embedded inside the reactor compartments. Their position shall be determined as precisely as possible and they shall be removed and separated from the concrete. The techniques and equipment for the process shall be developed at the design stage.

TASK 4
DETERMINING THE POSSIBILITIES OF THE DISPOSAL OF RADIOACTIVE WASTE

There are a few radioactive waste-related facilities in Estonia: Paldiski nuclear site, Tammiku radioactive waste storage facility and Sillamäe pond with tailings rich in natural radionuclides from production of rare earth metals. Paldiski nuclear site is the main radioactive waste source in Estonia.

According to the 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, it is the state’s responsibility to manage such waste.

The radioactive waste to be generated in the course of the decommissioning of the reactor compartments, which will commence in 2040 has to be disposed of in a radioactive waste repository established by that time at the latest. Therefore, according to the Estonian national policy, radioactive waste disposal facility must be operational by 2040. Even though Estonia is open to discuss other options, such as regional disposal, the current national radioactive waste management policy has been built on the principle that the radioactive waste generated in Estonia shall be managed and disposed of in Estonia. The environmental, technical and other analyses and studies necessary for the introduction of the repository must be started simultaneously with the environmental, technical and other analyses and studies necessary for the decommissioning of the reactor compartments.

Combination of a Near Surface Repository with Intermediate Depth Repository was found to be the best option for the needs of Estonia. This option was chosen for further consideration. Comparison of the disposal options was performed together with Estonian experts, including the opinion of the stakeholders.

Near Surface Repository should accommodate about 2100 m^3 of conditioned radioactive waste and Intermediate Depth Repository, 900 m^3 of conditioned waste.

General Waste Acceptance Criteria were produced for Estonian Near Surface Repository. A few different currently used waste packages and typical Estonian environmental conditions were considered.

The following sites are recommended for further investigation regarding suitability for establishment of a repository: Pakri peninsula (territory of the Paldiski navy centre), Rutja site and Rebala site. **Waste conditioning and transportation processes could be significantly simplified if waste disposal site were to be selected within the Paldiski navy centre or its vicinity**. Rutja site fits construction of both repository types well while Rebala site is less suitable for a Near Surface Repository. However, the sites are not well investigated yet and some relevant data are missing. A much more comprehensive analysis has to be done during the EIA.

The results of current preliminary studies have an important input in the choice of the concept of the disposal facility and the decommissioning of the Paldiski reactor compartments. It has been determined in the course of the current project that construction of a repository in Estonia and disposal of radioactive waste is feasible. At the current stage, however, the waste disposal process can be defined only at the conceptual level because of lack of reliable data on characteristics of the waste to be disposed of. Therefore, waste characterization has to be substantially improved by introducing methods for measurement of beta and alpha radionuclides in the raw waste.

Since the activities related to radioactive waste management, especially the construction of the disposal facilities are currently under the attention and great interest of the public, the public must be involved in the initial stage of the activities in order to avoid problems in the future. Also, it is highly recommended to investigate suitability of current radioactive waste sites for introduction of an appropriate disposal facility, because people living in the vicinity of nuclear sites are better informed about safety of radioactive waste and have less negative opinion on construction of new radioactive management facilities.

The following conclusions were made during this preliminary study:

- **Construction of a repository in Estonia and disposal of radioactive waste is a feasible solution and the only sustainable option.**

- Considering radioactive waste volumes and activities arising from RC decommissioning it is obvious that storage of such waste in Paldiski interim storage is not a safe solution. Renovation of the existing interim storage or construction of a new one is only a temporary solution, considering human and environmental safety, not a long-term alternative to disposal.

- A combination of underground disposal modules with disposal vaults built on the ground is the most appropriate disposal solution. Conceptually different disposal modules can be built on the same site, but can also be located on two separate sites that are better suited to different site requirements if selection of a single site suitable for both disposal options is not successful.

- The territory adjoining the Paldiski navy centre is regarded as a potential site for construction of a waste disposal facility. Waste conditioning and transportation can be substantially simplified were the waste disposal to take place in the vicinity of the centre. The other identified potential disposal sites are Rutja and Rebala. They are the main candidate sites to be investigated in detail during the EIA process.

- There is no information available about a shared radioactive waste disposal solution in any other country in the world. Generally all countries have similarly to Estonia prohibited the export of RW for disposal purposes (Estonian Radiation act § 61 section 10 point 6). Despite general discussions about regional disposal options there is no initiative from any country to host a regional repository. As establishment of any repository is very time consuming it can be assumed there will be no regional repository solution available within the next 50 years. And generally a regional solution is meant for spent fuel and HLW. For LLW and ILW every country has to develop its own disposal options.

The results of the current study have preliminary character only, as many relevant data are still missing. It should be followed by a more detailed investigation.

TASK 5
COST OF WASTE MANAGEMENT, DECOMMISSIONING OF THE REACTOR COMPARTMENTS AND DISPOSAL

The purpose of Task 5 is to estimate the cost on RW management, decommissioning of reactor compartments and also RW disposal.

In order to fulfil this purpose the following subtasks have been developed:

- Development of Methods for estimation of the cost of RW management (including analysis of ALARA Methods for cost estimation of RW management)
- Development of Methods for estimation of the cost of decommissioning of the RCs
- Development of the Plan of short-term and long-term measures

1. During development of Methods for estimation of the cost of RW management the following assumptions have been taken into account:

- Developed Methods will not consider RW remelting. For the case of the remelting option – the volume of the RW after remelting shall be included in the Methods.
- These Methods will be applicable for accumulated RW, RW generated during decommissioning and annual institutional RW.
- Information on the volume of the RW has been taken from Task 2 and Task 3 reports.
- The existing ALARA's Methodology has been considered as well.
- Three types of final stage of RW management are considered:
    - disposal in the near-surface repository;
    - disposal in the intermediate depth repository;
    - long-term storage with subsequent release from the radiation control.
- Total expenses are determined in prices measured for the year of 2015 in Euro.
- Calculations take into account inflation rate for the corresponding years (2016 – 2050).
- The Methods for cost estimation of RW management take into consideration agreed types of packages for RW disposal.
- All costs are presented without VAT and unexpected costs.

2. During development of Methods for RCs decommissioning cost estimation the following assumptions have been taken into account:

- Methodological approaches are based on the selected concept B – RC dismantling with small-size fragmentation (Task 3).
- The Methods are based on the indexes of labour input required for decommissioning under concept B.
- Total expenses are determined in prices measured for the year of 2015 in Euro.
- Calculations take into account inflation rate for the corresponding years (2016 – 2050).

3. During development of plans of short-term and long-term measures for decommissioning/establishment of a repository/RW management etc., the following assumptions have been taken into account:

- The schedule of short-term and long-term measures has been developed considering the National program for radioactive waste management
- Cost of some activities (such as: development of design documentation, EIA report etc.) have been made based on expert estimation

- Total expenses are determined in prices measured for the year of 2015 in Euro.
- Calculations take into account the inflation rate for the corresponding years (2016 – 2050).

Main conclusions:

Main conclusions are presented for the basic scenario. There is also basic pessimistic scenario, negative scenario and negative pessimistic scenario covered in the report.

The cost of preparation and implementation of the communication strategy on the establishment of the place of disposal and the liquidation of the reactor compartments is 0.49 million Euro (in prices of 2015, cost estimation doesn’t include VAT and unexpected costs).

The key point is establishment of a repository in Estonia. This will require every possible effort in the near future.

The cost of site selection and preparation of a safety analysis is approximately 2.7 million euro (in 2015 prices).

It is planned to have the repository established by 2039. The repository site shall include a near-surface and intermediate depth repositories. The total cost of siting, design and construction of the repository is 12.54 million euro (in 2015 prices).

The tariff for radioactive waste management should be increased because the volume of the repository will be smaller (in comparison with European repositories) and therefore the costs for disposal of 1 m^3 of waste will be above the average European level.

According to the concept for decommissioning, the reactor compartment hulls and all reactor equipment (except for the reactor vessels and steam generators) will be dismantled and fragmented (decision on steam generator fragmentation can be made at the decommissioning stage). These operations are planned to take place after 2039.

A key condition for implementation of this concept is to maintain stability of the main technological building up to 2050. In the near future, a comprehensive engineering and radiological survey of the main technological building and site should be done to confirm if this is possible. Comprehensive engineering and radiological survey cost is estimated at 540 thousand euro (in 2015 prices).

A “packaging” workshop capable of decontamination and conditioning of radioactive waste is planned to be established for the treatment of radioactive waste that will be generated during decommissioning of the reactor compartments.

Establishment of a “packaging” workshop by 2035 (before decommissioning of the reactor compartments) will make it possible to begin conditioning of accumulated radioactive waste at the Paldiski site. Cost of establishment of a “packaging” workshop is 6.64 million euro (2015 price), including the purchase of equipment.

In view of the establishment of a "packaging" shop and purchase of equipment, the cost of decommissioning of the reactor compartments is 19.47 million euro (in 2015 prices).

The cost of radioactive waste management (without the cost of procurement of containers) was calculated with consideration for storage, conditioning, transportation and disposal for the period between 2040 and 2050 and totals 33.15 million euro, including:

- radioactive waste from decommissioning of the reactor compartments – 15.96 million euro
- accumulated radioactive waste – 15.61 million euro
- annually generated in Estonia (up to 2040) – 1.58 million euro.

Procurement of containers for radioactive waste is 14.9 million euro, including:

- packages for disposal of accumulated radioactive waste – 3.96 million euro
- packages for disposal of radioactive waste resulting from decommissioning – 10.87 million euro
- packages for disposal of radioactive waste to be annually generated (until 2040) – 0.07 million euro.

Calculation of radioactive waste management is based on/includes capital expenses, operational expenses and closure of the repository and packaging shop.

The total cost of establishment of the repository, decommissioning of the reactor compartments, etc. is estimated at 67.5 million euro (in 2015 prices). The prices of corresponding years (taking into account the factor of inflation) could be 90 million euro. Calculations do not include unexpected costs or VAT (20%).

TASK 6
COMMUNICATION STRATEGY

The main objective of task 6 was to develop a communication strategy required for the decommissioning of the 2 nuclear reactor compartments of the former Paldiski navy training site and the establishment of the radioactive waste repository in Estonia. It also looks at how citizens and other relevant actors can be included in the decision making process in such a way that their input enriches the outcome towards a more socially robust and sustainable solution. Finally, it aims for the preparation of the communication strategy implementation plan, which also includes a time schedule for the measures to be implemented under the strategy, to identify the prerequisites necessary for the implementation of the measures and to estimate the costs of these measures. The communication strategy for increasing of awareness related to decommissioning and radioactive waste in Estonia is for the entire period of 2015-2050.

In order to meet these objectives the current situation in Estonia is described and analyzed, covering the social, economic and political situation, the existing information channels, and data from public opinion surveys.

Estonia, with the population of 1.36 million is a home for more than 100 different nationalities and ethnic groups, the largest of these being: Estonians about 70.0% and Russians about 25.5%.

These two communities can be characterized by their distinctly separate media consumption patterns.

The most important nuclear facility in Estonia are two nuclear submarine reactors of the former Soviet Union in long term storage stage at the Paldiski site. The site is managed by AS A.L.A.R.A, which is a state-owned company also managing other radioactive waste in Estonia, that is also responsible for decontamination of the site in question.

Paldiski is a town and Baltic Sea port situated on the Pakri peninsula of north-western Estonia. Paldiski is just under 50 km away from Tallinn and is easily accessible. The town has about 4300 inhabitants. The majority of its residents are ethnic Russians. Paldiski has a City Council and City Government. There are two schools in Paldiski: Paldiski Gymnasium and Russian Basic School. There is a library and an open internet cafe.

Today Paldiski is the centre of transit trade due to its cargo and passenger ports. Paldiski Harbour is ice-free during winters. The two ports – North and South are handling large volumes of traffic. Great investments have been put into the two ports and their facilities with a number of new berths having been created. Construction of a receiving liquefied natural gas terminal near the Paldiski town is also under consideration.

At present a general development plan for the next 10 years envisages the following main developments: harbour development, metal works, recreation and tourism, nature park, logistics centre, and wind farm construction. The Pakri wind farm has already been completed in 2004. Also, there is Paldiski South Harbour Industrial Park with surface area of 21 ha close to the harbour. Since 1 January 2011 the Northern Port of Paldiski has received the status of a free economic zone.

International experience shows that the communities with experience of nuclear installations have better knowledge and understanding of the life processes of nuclear reactors, radioactive waste management and peculiarities of its disposal. International practice shows that such communities tend to accept harmonized and consistent methodologies of decommissioning, radioactive waste management and disposal. Greater employment opportunities could be related to construction of the disposal facility.

Radiation and nuclear safety policy in Estonia is mainly shaped by 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 this process. The Minister of the Environment establishes the radioactive waste management program that directs the policy. The interim storage and final disposal of radioactive waste is organized by the Ministry of Economic Affairs and Communications to which AS A.L.A.R.A. reports.

The last public opinion survey regarding radioactive waste management is the Special Eurobarometer Survey “Attitudes towards Radioactive Waste”, conducted in 2008, whereby Estonian public opinion data were analysed and conclusions presented. 30% of respondents in Estonia consider themselves to be well informed about radioactive waste according to this survey. Scientists are seen as the most trustworthy source of information about radioactive waste management. 66 per cent of respondents have stated that they trusted information about radioactive waste given by scientists. Scientists are followed by international organizations working on peaceful uses of nuclear technology such as the International Atomic Energy Agency. 95% of respondents in Estonia agree that a solution for high level radioactive waste should be developed now and not left for future generation. 50% of Estonians agree that the disposal of radioactive waste can be done in a safe manner and 41% disagree with that fact. A large majority in Estonia (71%) mentioned television as the main source of information about nuclear issues. Television is followed respectively by newspapers, radio and the internet. The general Eurobarometer conclusion is that while people know little about radioactive waste, they feel concerned about it and have very little trust in the nuclear industry. It shows that increasing the level of information concerning radioactive waste among citizens could diminish their worries about the effects of radioactive waste on the environment and health.

The main information channels for accessing general public are mass media. Plenty of daily and weekly papers, magazines, seven domestic television channels, five of which are nationally broadcasted and over 35 radio stations are available within the 45,000 km^2 of Estonia. Paldiski town has local monthly newspaper Paldiski published in Estonian and Russian languages. The Internet in Estonia has one of the highest penetration rates in the world. Nearly all the newspapers in Estonia have their own website to publish some extracts or the whole contents of their print edition. The larger newspapers also run an online news-service with regular updates. Most of radio stations in Estonia have a parallel stream running on the Internet as well. Print media, radio media, television media and Internet consumption in Estonia are described in the report.

The strategy sets out two main objectives:

1. The public should be objectively informed ensuring the transparency of decommissioning and radioactive waste disposal process.
2. Public acceptance for the implementation of the decommissioning and radioactive waste disposal projects should be gained.

A number of tasks were defined for reaching the goals in the communication strategy and, taking into consideration the facts of the social, economic and political situation, the data and conclusions of the last public opinion survey and set objectives, target audience groups have been set out and described.

The main communication principles in decommissioning and radioactive waste management were defined in this document - a key requirement for communication is transparency: the need to better inform the public about decommissioning and radioactive waste and, through wider consultation, involve them more in the decision-making process concerning the management of the waste. Existing and proposed new European legislation not only encourages this provision of information and public involvement in the decision-making process, but actually requires it.

The present communication strategy is designed to fulfil this requirement by defining key messages to be conveyed:

- Decommissioning is the only sustainable solution for the final management of shut-down nuclear reactors;
- Radioactive waste already exists in all countries having nuclear programs and requires safe management and disposal;
- Storage is a temporary solution only and not as safe as disposal;
- Radioactive waste disposal is a very safe and sustainable long-term solution that many countries use;
- The radiation doses which can be expected from proper waste disposal are trivial when compared with those from natural sources of radiation or the effects of radioactive fallout;
- Nuclear waste disposal is less polluting compared to other waste produced;
- All radioactive waste can be managed in a safe and sustainable way;
- Any unsolved radioactive waste management problems shall not be left for the future generations.

Public information, awareness and transparency are ensured through various activities - Communication channels, means and tactics are required for fulfilment of the tasks and to reach the strategic objectives.

The institution responsible for the communication strategy implementation will be the Ministry of Economic Affairs and Communications. The ministry will supervise and coordinate the activities of other state institutions which will work as partners.

A communication strategy implementation plan has also been developed for the strategy. The plan is for the period during which the reactor compartments will be decommissioned and the final disposal facility will be established, activities taking place between 2017-2045 (according to the National Program for Radioactive Waste Management. The most important period for communication is when the environmental impact assessments of the final disposal site and decommissioning of reactor compartments are carried out (2017-2027). The main decisions should be made during this period. Also the public should be given the necessary opportunities to participate effectively in the decision-making process regarding the decommissioning and radioactive waste management. The most detailed planning is for the first period (2017-2027) with recommendations for concrete actions and first five year (2016-2020) budget (total 209.4 thousand Euro, VAT included). Every five years the plan has to be reviewed and corrected. It is recommended to perform a public opinion survey every five years and correct the communication plan on the basis of the opinion survey results.

This report is based on international experience and IAEA recommendations and is compiled in accordance with the National Program for Radioactive Waste Management in Estonia, the Environmental Impact Assessment and Environmental Management System Act, European Council Directive 2011/70/EURATOM on the responsible and safe management of spent fuel and radioactive waste, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, the Convention on Environmental Impact Assessment in a Transboundary Context (ESPOO Convention).

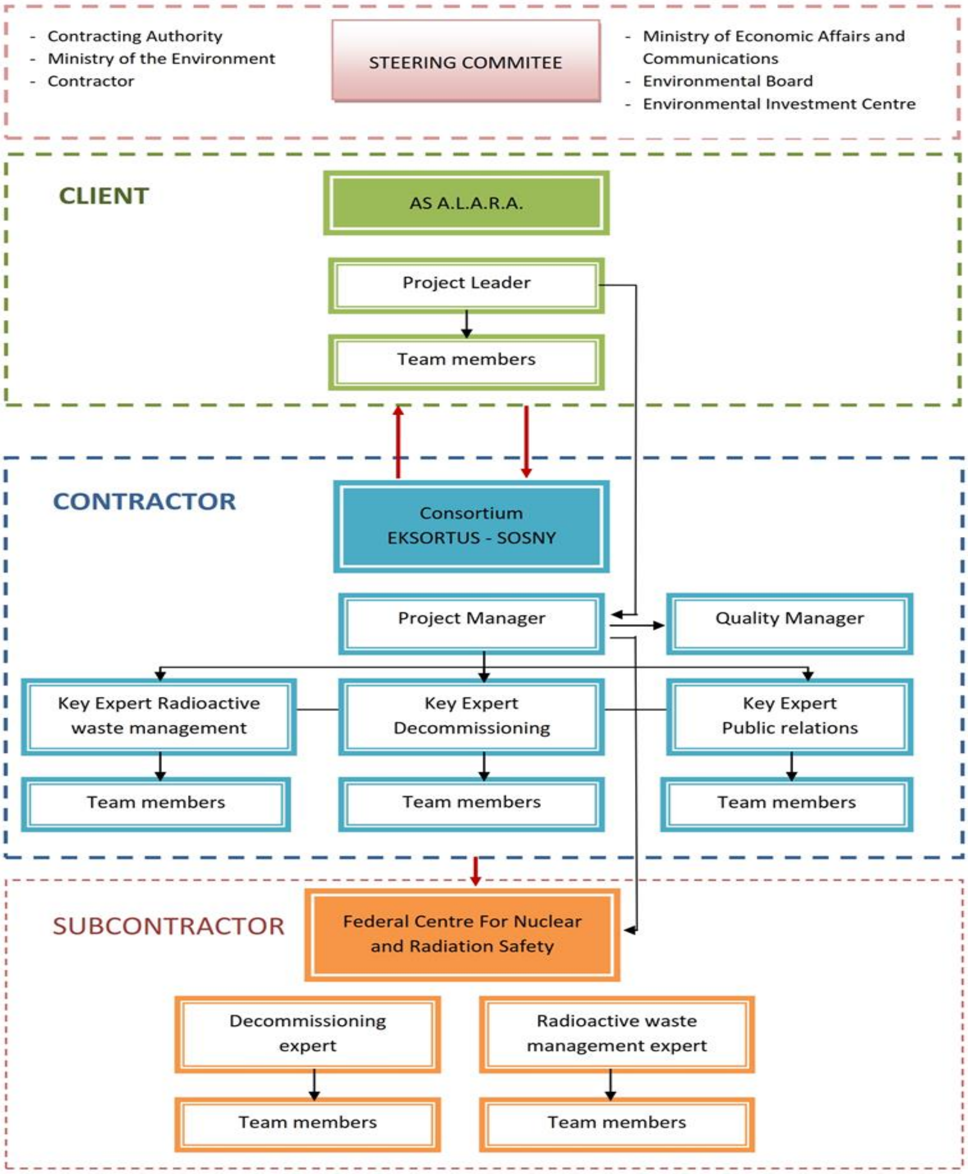
3. TASK 1 ORGANIZATIONAL PROJECT ACTIVITIES

The contract was implemented by a consortium of “UAB EKSORTUS – Research and Development Company SOSNY”.

In order to support the consortium in implementation of tasks 2, 3 and 5 the Contractor subcontracted the **Federal Centre for Nuclear and Radiation Safety** (Russian Federation) which is a corporate member of the State Atomic Energy Corporation ROSATOM.

In order to support the consortium in implementation of task 4 the Contractor subcontracted **Specialus Montažas – NTP** (Lithuania).

The scheme below presents the general structure of the Project organizational chart:



The organizational project activities consisted of five main events:

Introductory seminar. The seminar took place on 14 November 2014 in Estonia, in English and Estonian as working languages, in which all the project parties and the representatives of stakeholders took part. It was aimed at informing the participants of the project objectives and plans and the means of implementation thereof, and at discussing any possible unresolved issues. The presentation can be accessed online http://www.alara.ee/seminar1.php

Technical seminar No. 1. The seminar took place on 7-12 September 2015 in Visaginas, Lithuania with the purpose of informing the Client and Estonian stakeholders about the decommissioning-related experience of Lithuania. Specialists from Ignalina Nuclear Power Plant (INPP) presented their experience in decommissioning works of reactor equipment at INPP. Russian companies FCNRS, JSC “PDC UGR” presented experience of decommissioning of the reactor compartments in the Russian Federation. The seminar also included site visit on site of INPP where decommissioning works were ongoing. The topics presented can be accessed online: http://www.alara.ee/seminar2.php. During the seminar participants also discussed the results achieved through implementation of tasks 2 and 3.

Technical seminar No. 2. The seminar took place on 16-20 November 2015 in French National Radioactive Waste Management Agency (ANDRA) with the purpose of informing the Client and Estonian stakeholders about radioactive waste disposal experience in France. Experts from ANDRA presented disposal-related experience of France on the example of CSA and CIRES storage facilities. In addition, experience of Lithuania in radioactive waste disposal was presented by EKSORTUS to the participants. The topics presented can be accessed online: http://www.alara.ee/seminar3.php. For practical familiarization with the facilities ANDRA organized site visits to CSA and CIRES. During the seminar participants also discussed the results achieved through implementation of tasks 4 and 5.

Final report. The Contractor prepared Final Report covering all six Tasks (and activities) listed in the technical specifications of the project in English and Estonian languages. The Report describes the main objectives, assumptions made and the main conclusions drawn during implementation of each task. Main results of the whole Project are provided in the general summary of the Report.

Final seminar. The Final Seminar took place on 14 December 2015 in the Estonian Ministry of Environment in Tallinn in Estonian and English as the working languages. The purpose of the seminar was informing all the project parties and the representatives of stakeholders of the Project results. Presented topics can be accessed online: http://www.alara.ee/seminar4.php.

The deliverables for the project included the reports for each of the six tasks (please refer to the SCOPE OF WORK). All deliverables of the Project were submitted by the Contractor in accordance with the approved Project schedule.

The scope of work on the Project comprised 6 major tasks.

Task 1 – Organizational project activities

The task is dedicated to project management, planning and reporting activities. Also, this task establishes the framework for project implementation. In the course of the Project implementation the Contractor has organized 4 seminars:

- Introductory seminar
- Technical seminar No. 1 dedicated to the decommissioning of reactor compartments
- Technical seminar No. 2 dedicated to radioactive waste disposal
- Final seminar dedicated to Project results

The Contractor also prepared the Final Report covering all six Tasks listed in the technical specifications of the project in English and Estonian languages.

Task 2 – Collection of data and overview of national and international requirements

- Collection and analysis of the available data concerning the reactor compartments and other related aspects
- Overview of international and national recommendations and legal acts on the decommissioning of reactor sections
- Overview of international and national recommendations and legal acts on the disposal of radioactive waste

Task 3 – Determining the possibilities of decommissioning the reactor compartments

- Assessment of different methods used for decommissioning of reactor compartments
- Comparative assessment of alternative methods used for decommissioning of reactor compartments
- Development of the concept of decommissioning selected as a result of the assessment
- Description and assessment of the waste to be generated in the course of the decommissioning works
- Decommissioning safety assessment taking into account the quantities of waste to be generated

Task 4 – Determining the possibilities of the disposal of radioactive waste

- Analysis of different options for the disposal of radioactive waste in Estonia
- Strategic concept of waste disposal
- Mapping of suitable areas using GIS software/database

Task 5 – Cost of waste management, decommissioning of the reactor compartments and disposal

- Development of methods for estimation of the cost of radioactive waste management
- Development of methods for estimation of the cost of decommissioning the reactor compartments
- Estimated cost of reactor compartment decommissioning
- Plan of long-term measures and the related costs in waste disposal
- Plan of short-term measures and the related costs in waste disposal
- Institutional aspects and sensitivity analysis

Task 6 – Communication strategy

- Communication strategy implementation plan
- Development of a communication strategy (including public communication) required for the decommissioning of the reactor compartments and the establishment of the repository

4. TASK 2 COLLECTION OF DATA AND OVERVIEW OF NATIONAL AND INTERNATIONAL REQUIREMENTS

The main goals of this task were:

- review and analyze available data concerning the reactor compartments of the former Paldiski military nuclear site and the establishment of a radioactive waste repository;
- review IAEA, European Union, Estonian Republic and Russian Federation regulations relating to the area of decommissioning of NS reactor compartments, which shall be observed upon making decisions on decommissioning of the reactor compartments of the former Paldiski military nuclear site;
- review the documents of the IAEA, European Union, Republic of Estonia and Russian Federation, regulating radioactive waste disposal, eliciting requirements to the radioactive waste disposal, which shall be observed under making decisions on the permanent radioactive waste disposal generated under decommissioning of the reactor blocks of the former Paldiski military facility.

The task made a detailed and thorough analysis of the available data on the reactor components at the Paldiski site and the inventory of radioactive material at the site. The following areas were dealt with in the task report:

4.1 Collection and analysis of the available data concerning the reactor compartments and other related aspects

The data available were analyzed with regard to the origin, operation and decommissioning of Reactor Units of the Former Training Centre of the Naval Force of the Russian Federation in the Pakri Peninsula. The report provides the basic Technical Specifications of the reactors, analyzes the work done so far on the decommissioning of the Reactor Units at the Training Centre in Paldiski and presents the key parameters of the process equipment (steam generators, main circulation pumps, filters, refrigeration units, pressurizers, heat-exchangers, etc.), including radiological characterization, in the reactor units 346A and 346B.

Significant steps have already been achieved in the preparation of the Units for long-term storage, however, there still remains a need for additional data to be collected, surveys and studies performed, e.g. Comprehensive Engineering and Radiation Survey, in order to commence the decommissioning process.

Comprehensive Engineering and Radiation Survey of the Main Technological Building shall consist of an engineering and a radiation survey and be performed by a commission set up by authorities.

The results of Comprehensive Engineering and Radiation Survey of the Main Technological Building shall provide the basis for justification of the preferred option for facility decommissioning and development of a decommissioning design based on the selected option. It shall also include review of the design documentation, reactor operation history, obtaining data on the present condition of structures, systems and components. An additional analysis has to be performed to verify the use of the existing equipment (e.g. lifting and handling equipment, electricity and water supply, drainage, ventilation, radiation monitoring system, etc.).

Also, additional Engineering and Radiological investigations of the Main Technological Building have to be performed.

Based on the analysis of the existing nuclear power plants with modern reactor designs, this section gives indicators of radioactive waste volumes to be generated during the operation and decommissioning of a possible nuclear power plant in the Republic of Estonia with a water-cooled single reactor design with approximate capacity of 1,000 MW.

Indicative waste amounts have also been provided for the waste from decommissioning of units 346A and 346B and other waste stored in containers and drums at the Paldiski site, for various decommissioning options.

CONCLUSIONS, Subtask 1

Main components of unit 346A are

- reactor vessel VM-A with vessel volume ca 18 m^3 and weight 30 tons;
- steam generators (8 pcs);
- circulation pumps (2 pc);
- pressure compensators (6 pcs);
- heat exchangers (4 pcs);
- reactor heat carrier cleaning filters (2 pcs);
- iron-water protection tank with dimensions 2300x2300x3200 mm and weight 52 tons.

Other important facts about unit 346A:

- dose contributors Co-60, Fe-55, Ni-59, Ni-63;
- total activity of nuclear power unit $1{,}5 \times 10^{14}$ Bq (2015);
- total amount of water remains about 1370 l (360 liters of water in the primary cooling circuit with a total inventory of 2.2 MBq/l (1989) and ca 1000 l secondary cooling circuit with activity 4,07 Bq/l (1994)). The main radionuclides Cs-137, Co-60, Sr-90 and H-3;
- there is no non-fixed contamination present on outer surfaces of equipment and pipelines inside RC;
- about 100 sealed sources with total activity ca 4,4 TBq (1995) and 14 tons solid LLW were put inside the unit (rags, tools, metallic waste etc.) and covered with concrete. Most probably sealed sources and waste were put in the upper part of the reactor location (lid area). If the sources and waste are to be looked for, the search shall start from the upper part of the reactor entombment;
- reactor compartment was filled with concrete up to second floor, totally 30,75 m^3 of concrete were poured inside RC;
- after the final shut-down of the reactors a radiological survey of internal reactor rooms was undertaken;
- according to calculations, build-up of long-lived radionuclides activity is ca 312 TBq (2001). Radionuclide composition as of 2001 was following (%): Co-60 – 39.2; Fe-55 – 30.0; Ni-59 – 0.3; Ni-63 – 30.3;

Detailed technical characteristics, material and design of the systems are presented in Task 2 report. The nuclear simulator units were operated in accordance with a training program, and their operating conditions only envisaged running at 20 ÷ 40% of nominal reactor power, with rather frequent complete shut-downs. No considerable abnormalities or accident situations have been recorded. No cases of fuel element breach were registered either.
The space in front of the iron-water protection tank was filled with concrete blocks during simulator construction to improve radiation shielding. Calculations have determined that the concrete should be activated as a consequence of being hit by neutrons emitted from the reactor to the depth of about 0.5 m from the wall of the iron-water protection tank.
In accordance with the general approach used in the Russian Federation and based on the statistical data of operational experience of water-pressured reactor units, the majority of induced radioactivity (up to 99 %), disregarding nuclear fuel, tends to concentrate in the reactor vessel because reactor pressure vessel is under neutron flux. Second most radioactive piece of equipment is iron-water protection tank (protects other equipment from neutron flux), which accumulates about 1 %, with the balance of equipment in the primary circuit accountable for fractions of a percent of total radioactivity of the nuclear power unit.

Main components of unit 346B are:

- reactor vessel VM-4 with volume ca 30,3 m^3 and weight 50,4 tons;
- steam generators together with primary circulation pump (5 pcs);
- pressure compensators (3 pcs);
- primary circuit filter refrigerator;
- electric cool-down pump;
- reactor heat carrier cleaning filters (2 pcs);
- iron-water protection tank with dimensions 2565x4860x6140 mm and weight 66 tons.

Other important facts about unit 346B:

- dose contributors Co-60, Fe-55, Ni-59, Ni-63; Nb-94;
- total activity of nuclear power unit 2,9x10^{13} Bq (2015);
- total amount of water remains about 2280 l (600 liters of water in the primary cooling circuit with a total inventory of 1 MBq/l (1989) and ca 1680 l in 2nd, 3rd and 4th loop. The main radionuclides are Cs-137, Co-60, Sr-90;
- volumes and activities of water remaining in the second, third and fourth circuits are not recorded;
- solid metallic LLW were put inside the unit (tools, loading equipment, electrical equipment etc.) and covered with concrete. Most probably metallic LLW waste was put in the upper part of the reactor location (lid area). If the sources and waste are to be looked for, the search shall start from the upper part of the reactor entombment;
- reactor compartment was filled with concrete up to second floor, totally 41,25 m^3 of concrete were poured inside RC;

Detailed technical characteristics, material and design of the systems are presented in Task 2 report. As 346B was second generation technology it was designed in consideration of the first-generation unit weaknesses. In view of this, the nuclear power unit design layout was changed. Its scheme remained loop-based but configuration and size of the primary circuit were significantly reduced. The “pipe-in-pipe” configuration was adopted and primary circuit pumps would “hang” on the steam generators. The quantity of the big-diameter piping of the main equipment (primary circuit filter, pressurizers, etc.) was reduced. The majority of the primary circuit piping (large and small diameter) were positioned within the premises under the biological shielding. Reactor stand was in operation only for a relatively short period of time (1983 to 1989). During this period, the reactor unit actually ran for only 5,333 hours at 20 – 40% of nominal power. No noticeable deviations in simulator operation were recorded. Radiological conditions in work rooms of the stand were normal and stable.

Other important facts:

- there were no accidents related to the radiological emergency in the main technological section during the entire period of operation of both installations. No man-induced pollution of the environment (soil, vegetation, groundwater, etc.) nor of the surrounding areas was observed over the period of long-term observations;
- before erecting reinforced concrete shelters around the reactor compartments, during 1995, a radiological survey was made of the external surfaces of the reactor compartments. The highest radioactivity on the reactor compartment shells was spotted directly under the reactor, 1.5-2.0 m in diameter. On the remaining surface of the shell, ionizing radiation rate is close to background levels. Ionizing radiation rate under the reactor of stand 346B has a much smaller value due to design reinforcement of the biological shield and reduced energy yield.

Collected data is sufficient to develop options for reactor compartment decommissioning and assess the volume and radioactivity of the waste produced. During reactor compartment storage no above-level emissions and discharges of radioactivity into the environment have been detected. During indicative analysis of radioactive waste volumes, including operation and decommissioning of a possible NPP in the Estonian Republic, a 1000 MW PWR reactor was assumed as the basis. Westinghouse (USA) AP-1000 was assumed as the prototype reactor with VVER-1000 (Russia) serving as alternative. The following assumptions were made:

- nuclear fuel will be leased and returned later to the producer. Only operational and decommissioning waste will be managed in Estonia;
- the reactor will be commissioned 2030;
- operational period of reactor 60 years.

Estimated total amount of conditioned radioactive waste expected to be generated during operation and decommissioning of a power plant with AP-1000 unit is at least 15 401.5 m^3.

Four decommissioning options were considered during assessment of waste arising from Paldiski RC decommissioning:

A - dismantling with fragmentation into large pieces;
B - dismantling with fragmentation into small pieces;

C and D – disposal as one piece (entombment and near surface disposal).Options C and D were considered only as alternatives because those options are not internationally accepted for disposal.

Estimated radioactive waste amounts generated from Paldiski reactor decommissioning are as follows:

Concept A – ILW and LLW radioactive waste 732 m^3, non-radioactive waste 2000 m^3;
Concept B – ILW and LLW radioactive waste 519 m^3, non-radioactive waste 2130 m^3;
Concepts C and D – ILW and LLW radioactive waste 1545 m^3, non-radioactive waste 1260 m^3;

Existing radioactive waste amount stored in Paldiski site interim storage facility and at control area is 985 m^3.

Due to the uncertainties in data and partial lack of reliable data for planning of decommissioning, it is recommended to make a comprehensive engineering and radiation survey of the Paldiski facility prior to decommissioning as there is lack of operational documentation and history records on surveys and monitoring. The main task of comprehensive engineering and radiation survey (CERS) would be to assess actual radiation and technical condition of the facility and its radiological and non-radiological hazards. The results have to be available before environmental impact assessment report and they should serve as informational base to justify the facility decommissioning option and to develop a decommissioning project for the option preferred. It is assumed that it would be reasonable to divide CERS into several phases:

1) it is recommended to perform engineering survey of the MTB structures and stack to verify their current condition and determine how it could affect the decommissioning process (e.g. based on the engineering survey conclusions - MTB could be used as a shelter during the dismantling process after corresponding stabilization works (if needed) or demolished prior to the RCs dismantling if the strength properties will not comply with the requirements);
2) as the design life-time period of the sarcophagi ends in 2045, it seems reasonable to perform the engineering survey of the sarcophagi structures and external structures of the RCs to obtain data for the beginning of the decommissioning stage. Based on the results of the engineering survey of the sarcophagi structures, recommendations for the stabilization measures will be given (if needed). In case of the decision to extend the storage period, additional surveys on geology, hydrogeology, wind and snow loads, etc. will be needed for calculations and safety justifications;
3) it is recommended to perform an engineering survey of the existing waste storage within the MTB. These surveys could be performed in several stages or simultaneously;
4) it is recommended to perform radiation survey of the RCs (including survey of the internals) to obtain actual data to be used as the basic data for the EIA, FS and design stage. It seems reasonable to perform this survey as close as possible to the starting point of the dismantling stage (depends on the decision whether to extend the storage period or not);
5) it is recommended to perform a survey of the site, including a radiation survey (and also geological, hydrogeological, seismic, etc. for the case of Paldiski site selection for disposal facility construction).

4.2. Overview of International and National Recommendations and Legal Acts on the Decommissioning of Reactor Sections

The subtask provides information on the management of the reactor compartments from decommissioned submarines in the countries with a Nuclear Submarine Fleet and then focuses on the legal requirements and standards for decommissioning as required by IAEA, the European Union and, in greater detail - the Republic of Estonia.

Detailed steps are provided in the form of "*Guidelines for Amending the Regulatory Framework of the Republic of Estonia to the Extent of Radiation Hazardous Facility Decommissioning*", including recommendations for the development of regulatory documents regarding decommissioning of radiological facilities and provides a preliminary schedule for the development and release of the regulatory documents to update the legal framework of the Republic of Estonia.

CONCLUSIONS, Subtask 2

Due to an obvious need for reactor compartment decommissioning at the Paldiski facility in the future, the Republic of Estonia shall continue developing radiation safety assurance during decommissioning of radiological facilities using the experience accumulated by other countries in the field of NPS decommissioning to guide its decision-making. A respective regulatory framework shall be used during practical implementation of decommissioning of the reactor compartments to ensure safety and compliance with EU and IAEA requirements.

Current legislation of the Republic of Estonia does not provide for precise responsibility breakdown in the process of radioactive waste handling. Responsibilities and liabilities of participants have to be determined. Furthermore, some legislative acts enforced in the European Union impose additional obligations on the Republic of Estonia and those obligations have to be stipulated in the Estonian legal framework to ensure their fulfilment.

Directive 2011/70/EURATOM came into effect in 2011 establishing responsible and safe management of radioactive waste and spent fuel in the European Union imposing upon each EU Member State an obligation to prepare a national program and submit it to the Council describing waste collection and removal arrangements in the member state as well as measures taken to transfer waste for its final disposal. The action plan comprises a description of the state's policy on radioactive waste, existing unnecessary inventory, technical solutions for waste treatment and disposal (final disposal), time periods for actions, resources, etc.

The review and analysis of normative documents of the IAEA, European Union, Russian Federation regulating nuclear and radiological facility decommissioning issues have been carried out within the framework of the Subtask.

The focus in the majority of documents is placed on the back end of hazardous nuclear and radiological facilities. It is vitally important to make such facilities (in this case the reactor compartments of the Paldiski site) radiologically safe and ensure environmental protection and safety of the population as well as relieve the future generations from the nuclear legacy burden.

Major issues to be resolved in the course of decommissioning include radiation protection assurance, treatment of radioactive waste to be generated and final disposal thereof.

International legal and regulatory framework prescribes that attention should be paid to identification of the after-effects of decommissioning activities on human health and environment.

IAEA recommendations and EURATOM Directives are based on the priorities of the population protection against hazardous exposure. The development of the decommissioning and RW management option in an EU Member State should be performed in a consensual and consultative environment and take into account the interests of other Member States. However, development of an individual decommissioning strategy is available for every Member State.

32 documents of the Republic of Estonia (state recommendations and regulations of the Republic of Estonia) related to decommissioning of nuclear and radiological facilities, which is defined as part of radioactive waste management activities and thus requires licensing for activities associated with radioactive materials, have been analyzed within the scope of the Subtask.

The analysis revealed the following:

- There are no special regulations regulating decommissioning of radiological facilities in the Republic of Estonia;
- The following documents shall remain unchanged: Regulation No.110, Environmental Monitoring Act; Regulation No.50; Regulation No.57; Regulation No.5 ; Road Transport Act; Industrial Emissions Act; Ambient Air Protection Act; Fire Safety Act;
- Recommendations are given for changes concerning general issues of radiations safety assurance and stages of radioactive waste handling with respect to the documents analysed.

Since decommissioning is determined as part of radioactive waste management activities, the requirements for RW management cover decommissioning as well.

Amendments related to the following points are proposed to be introduced into the main document, the Waste Act:

- Provision of a legal basis for licensing of stages of radiation material handling as decommissioning after closing down may be implemented both as one continuous operation or as a series of discontinuous operations over a long time period;
- Specification of the requirements for license application (the license application shall comprise, among other things, the following issues: fire protection and fire fighting for the whole site. Selection of various decommissioning options shall be developed considering a wide range of issues with special emphasis on the balance between safety requirements and decommissioning resources available at the time, etc.)
- Survey of residual radionuclides on the reactor site after completion of decontamination or dismantling to confirm that residual activity complies with the criteria established by the national regulator thus justifying achievement of the decommissioning objective;
- Provision of financial resources to cover expenses associated with safe decommissioning, including waste handling.

- Special attention shall be given to possible contamination due to generation and release of dust and aerosols of radioactive liquids as well as to large amount of waste generated during the decommissioning.

Changes are to be introduced into Regulation No.10 and into the Waste Act since large amount of metal waste are expected to be generated during the decommissioning.

Changes are to be introduced into the legislative and regulatory framework of the Republic of Estonia in view planned RW handling activities and updates to legal framework of the EU and IAEA.

Being an EU Member State the Republic of Estonia shall ensure adjustment to rules, directives and other documents issued at the EU level. EU Directives 96/29/ EURATOM, 2013/59/ EURATOM, 2003/122/ EURATOM, 2009/71/ EURATOM, 2011/70/ EURATOM are the most important documents in the sphere of radioactive waste.

Due to obvious need for decommissioning of the reactor compartments at the Paldiski facility in the future, the Republic of Estonia shall continue developing radiation safety assurance during decommissioning of radiological facilities using the experience accumulated by other countries in the field of NPS decommissioning to guide its decision-making.

It would be appropriate to engage experts from one of the countries with experience in NPS operation and decommissioning in order to develop amendments to certain regulations governing the reactor compartments decommissioning activities at the Paldiski facility.

Amendments introduced into legislative and regulatory framework of the Republic of Estonia shall be sufficient to develop design documentation for decommissioning of the reactor compartments at the Paldiski facility and carry out dismantling of the RC building structures and equipment based on design documents and respective licenses enabling the activities.

4.3. Overview of International and National Recommendations and Legal Acts on the Disposal of Radioactive Waste.

The subtask analyzes the applicability of IAEA documents developed to deal specifically with the disposal of radioactive waste:

- Disposal of radioactive waste, IAEA specific safety requirements NO.SSR-5, 2011;
- Near surface disposal facilities for radioactive waste. Specific safety guide NO.SSG-29, 2014;
- Geological disposal facilities for radioactive waste. Specific safety guide No. SSG-14;

and continues with the analysis of IAEA documents related to predisposal management of radioactive waste:

- Predisposal management of radioactive waste, IAEA general safety requirements part 5, 2010;
- Predisposal management of low and intermediate level radioactive waste, IAEA safety guide No. WS-G-2.5, 2005;

An Overview of IAEA Safety Standards on Classification of Radioactive Waste and its Transportation is provided by analysing the following documents:

- Classification of radioactive waste, IAEA General Safety Guide No. GSG-1, 2009;
- Regulations for the safe transport of radioactive material, IAEA specific safety requirements NO.SSR-6, 2012;

As the Republic of Estonia is a member state of the European Union, it is subject to the requirements of EURATOM documents, which entails the need for detailed analysis of not only a series of IAEA standards but also of EURATOM Directives regarding radioactive waste management and control of its transportation.

The subtask therefore provides an analysis of the legislative framework that is relvenat in the European Union, including an overview of EURATOM directives on management and transportation of radioactive waste and the potential influence these directives might have on the regulatory framework of the Republic of Estonia.

The main conclusions regarding the EURATOM directives concerning radioactive waste management

Based on content analysis of EURATOM Directives related to management of radioactive waste it is reasonable to recommend reorganization of the regulatory and legal framework of the Republic of Estonia related to radioactive waste management. As national legislation is in the exclusive competency of the member states of the EU, it is reasonable to presume the independency and individuality of documents ensuring complete compliance with the EURATOM recommendations and standards related to radioactive waste management and radiation safety. Making decisions concerning the final stage of fuel cycle should be based, first of all, on ethical component of not burdening the future generations with heritage of nuclear waste.

The problem concerning disposal of radioactive waste is described in clause 11 of Directive 2011/70/EURATOM, where it is stated that the problem of disposal of radioactive waste should be described in the National plan of a member state. Clause 37 of the Euratom Treaty stipulates that each member state should submit a plan for disposal of radioactive waste to the European Commission. Studying this plan in the expert community the Commission makes a resume concerning the consequences of realization of this plan in respect of possible radiological pollution. Clause 37 calls upon securing a radiation protection of all member states. Therefore the evaluation of pollution is conducted not only in respect of the country, which is the author of the disposal plan.

Therefore the problem of national disposal should be studied at the local regional level with further approval of the expert community of the European Commission.

Publication of new regulatory acts and their introduction into the entire structure of legal framework of the Republic of Estonia is a very important step which results in formation of national policy related to safe waste management. No amendments should be accepted without evidence and all such amendments should include economical budget analysis ascertaining the availability of a sufficient quantity of budget funds for practical implementation of adopted standards.

Therefore when developing national regulatory and legal documents in the Republic of Estonia related to management of radioactive waste it is required to observe the following EURATOM Directives:

- Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste;
- Council Directive 2013/59/EURATOM of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation,
- Council Directive 2006/117/EURATOM of 20 November 2006 on the supervision and control of shipments of radioactive waste and spent fuel.

The basic findings with respect to directives of EURATOM on transportation of radioactive waste

Provisions pertaining to export of radioactive waste to a third country are laid down in Directive 2011/70/Euratom, Article 4:

Radioactive waste is to be disposed of by the EC member-country, where it has been produced before the moment an agreement between EC member countries or a third country comes into effect taking into account a criterion established by the European Commission in accordance with Article 16 of Directive 2006/117/Euratom.

Before sending to the third country the EC member-country exporting the nuclear waste and spent fuel is obliged to inform the European Commission on the content of such an agreement and take reasonable measures to confirm that:

a) the destination country has closed a corresponding agreement with the European Commission comprising regulations on management of nuclear fuel and radioactive waste or is the party of the Single Convention on safe management of the nuclear waste and spent fuel ("Single Convention");

b) the destination country has available corresponding programs for providing high level of safety in management of nuclear waste and spent fuel equivalent to the provisions of this Directive;

c) before the moment of sending nuclear waste and spent fuel to the destination country the provisions on the disposal facilities of the destination country will be effective and governed on the basis of the rules on management of nuclear waste and programs of the given state on the disposal thereof.

Also, for comparison, an overview of the Russian Federation Recommendations and Legal Acts on Disposal of Radioactive Waste has been made, defining the structure and the basic principles of the relevant legal acts in the Russian Federation.

Finally, the legislative framework of the Republic of Estonia has been given a thorough analysis with the aim of establishing potential areas of improvement as regards the disposal of and transportation of radioactive waste. The *Recommendations on Introducing Changes Into Regulatory Framework of the Republic of Estonia With Respect to Disposal and Transportation of Radioactive Waste* are provided in clauses 3.8 and 3.9 of the report.

CONCLUSIONS, Subtask 3

The conducted overview and analysis of the IAEA, European Union, Russian Federation and Republic of Estonia regulatory documents that regulate final disposal of radioactive waste (Sections 3.1 to 3.7 above) have demonstrated the need for improvements to the existing legal provisions and regulatory documents in the Republic of Estonia in terms of incorporating requirements to ensure safety of radioactive waste disposal. The provisions of Estonian regulations must be responsive to advances in science and technology and today's view of safety as well as to recommendations of the International Commission on Radiological Protection, IAEA and EU.

Thirty-two Estonian documents have been analysed under this subtask.

This analysis resulted in identification of documents that contain sufficient requirements for radioactive waste disposal. Such documents include Regulation # 110 [*The Requirements for the Results of Individual Monitoring of Outside Workers, and for Formalizing Such Results, and for the Standard Format for the Dose Chart of Outside Workers*], the Environmental Monitoring Act; Regulation # 50 [*Establishment of National Environmental Monitoring Stations and Areas*]; Regulation # 57 [*Procedure of Notification of the Ministry of the Interior of An Emergency or of the Impending Risk of the Occurrence of An Emergency*]; Regulation # 5 [*The Guidelines for Preparing an Emergency Risk Assessment*]; the Road Transport Act; the Industrial Emissions Act; the Ambient Air Protection Act; the Fire Safety Act.

Part of the documents analysed provide recommendations for modifications to be made concerning general aspects of radiation safety regarding every stage of radioactive waste management.

Final disposal is the final stage in the radioactive waste management process. Therefore, all radiation protection principles and all requirements for radioactive waste management are applicable to this stage.

However, there are a number of special requirements suggested for incorporation into the legal and regulatory framework in the Republic of Estonia.

For instance, it is suggested that the principal document – the Radiation Act – should be amended to reflect the following:

- definition of the regulator's role in the stages of radioactive waste management site planning, design, construction and operation;
- definition of legal, technical and financial responsibilities for organisations involved in radioactive waste management activities in the course of radioactive waste disposal;
- definition of clear juridical, technical and financial responsibilities for organisations involved in the establishment of radioactive waste management facilities including all types of disposal ones;
- incorporation of options for waste disposal planning and implementation into the national policy;
- division of the activities at different stages of the disposal facility operation: pre-operational, operational and post-operational periods;
- the operator's responsibilities with respect to preparation of the commissioning report; requirements for information that this report should provide;
- requirements for planning of disposal facility shutdown (elaboration of shutdown solutions must be mandatory when such disposal facilities are designed);
- provision of the public with information concerning radioactive waste management with due regard for security and confidentiality issues;
- identification of specific requirements for the license owner who undertakes radioactive waste disposal activities;
- guidelines and details pertaining to studies and identification of site characteristics during the construction period and following site shutdown;
- any other issues associated with final disposal.

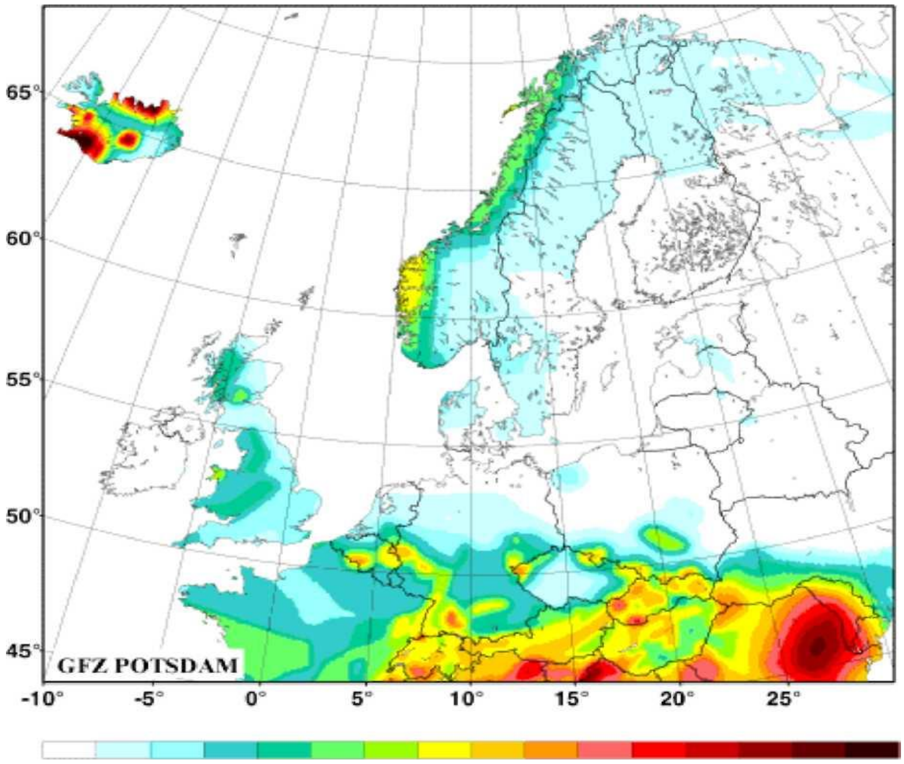
One of the main regulations – Regulation # 8 [*The Classification of Radioactive Waste, the Requirements for Registration, Management and Delivery of Radioactive Waste and the Acceptance Criteria for Radioactive Waste*] should be changed with regard to:

- review of the classification of radioactive waste taking into account the classification proposed by IAEA;
- development of the waste acceptance criteria for radioactive waste as part of the disposal facility design process;
- any other issues associated with acceptance of waste for final disposal and assessment safety thereof for the purposes of final disposal.

It should be noted that there is a need to control the exposure doses for members of the public and to consider dose pathways resulting from the disposal or recycling of solid residues. The recommended dose limit for specific types of exposure in a Member State is 1 μSv per year. Development of national legal and regulatory documents in the Republic of Estonia with regard to radioactive waste management and disposal should be based on the EURATOM Directives and IAEA standards and recommendations.

4.4. The indicative list of information for license applications of new EURATOM BSS is basically covered in the current legislation, but the aims of the safety assessment might be defined in a more detailed way. Also adequate defence in depth has to be ensured by demonstrating that there are multiple safety functions, that the fulfilment of individual safety functions is robust and that the performance of the various physical components of the disposal system and the safety functions they fulfil can be relied upon, as assumed in the safety case and supporting safety assessment. The long term safety of a disposal facility for radioactive waste is required not to be dependent on active institutional control. The intent of surveillance and monitoring is not to measure radiological parameters but to ensure the continuing fulfilment of safety functions. The issue of new and addenda to the existing legal and regulatory acts at the level of National Laws (in terms of legislation elaboration with regard to the tasks of decommissioning hazardous radiation facilities, radioactive waste management including final disposal and establishment of a unified national system for radioactive waste management), Government regulations (with regard to the identification of radioactive waste classification criteria; radioactive waste and storage facility registration, accountancy and control system; provisions of radioactive waste transfer for storage and disposal; regulation of tariffs and contributions for radioactive waste storage and disposal), regulations by Ministries (with regard to the specification of principles, criteria and safety requirements for radioactive waste collection, management, treatment, conditioning, transport, storage and final disposal including the establishment of waste acceptance and quality assurance criteria), and their incorporation into an integrated structure of the Estonian legal and regulatory framework is a vital step that entails the formation of the national policy with respect to ensuring safety of radioactive waste management. Any changes should be made only with reliance on the evidence base and must include comprehensive economic analysis that should confirm the availability of sufficient (budget) funds for the practical implementation of standards to be adopted. Input Data for the task 4 Related to the Establishment of the Disposal Facility

The basic geological and hydrogeological conditions, climate and other aspects relevant to potential establishment of a disposal facility in Estonia, such as regional geology, tectonics and seismicity, and stratigraphy, are covered in the present subtask. The results of geophysical Investigations in Pakri peninsula are presented and basic geological parameters important for the disposal site, i.e. ensuring stability of natural barriers and the movement of ground water, are discussed. It is also important that the potential site has to be away from surface water courses and water intake structures as well as protected areas, such as natural parks, big cities or sites with natural resources. An overview of potential sites for the disposal facility is presented together with the basic technical requirements for the disposal site.

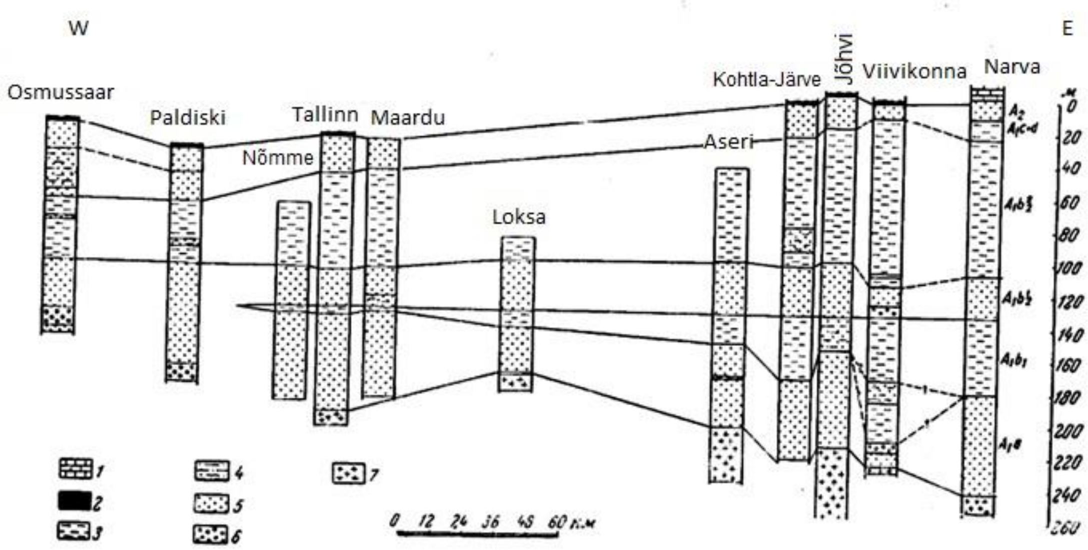


Peak horizontal seismic acceleration map with a 90% probability of stability in 50 years

CONCLUSIONS, Subtask 4

In the framework of the research carried out to collect input data for the implementation of Task 4 '*Determining the possibilities of the disposal of radioactive waste'* and Task 5 *'Cost of radioactive waste management and planning*' under these '*Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository*' the tasks that have been assigned high priority were included into *Recommendations for the identification of suitable locations of a potential radioactive waste disposal site*.

An indicative assessment has been made of the regional cartography/ mapping and studies in order to determine areas with potentially suitable locations based on geographic, geological and hydrogeological findings from previous surveys as well as historical data. Other factors that influence the siting of the disposal facility have been identified, such as the presence of mineral resources.



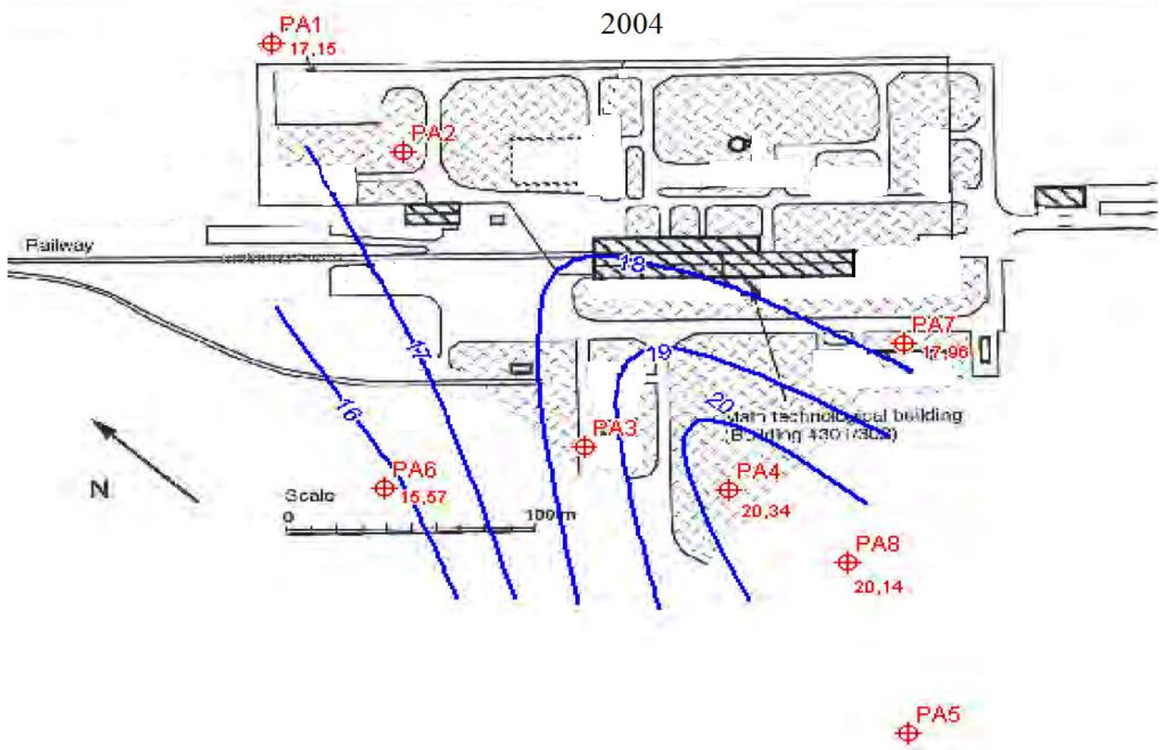
Schematic section of Cambrian in North Estonia (according to drilling data)
1-limestones (Ordovician); 2-dictyonema oil shale (Ordovician); 3-clays; 4-sandy clay and siltstones; 5-sandstones and sands; 6-coarse sandstones, gravel stones and pudding-stone; 7-Pre-Cambrian rocks

The following has been established as a result:

It was taken into consideration in the course of overview of archive data and the Client's data concerning geological, hydrogeological and weather conditions in the Republic of Estonia that the process of siting a radioactive waste disposal facility had to take into account technical and other considerations. Technical factors cover a long list: geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, human-induced events, transportation of waste, land use, population distribution and environmental protection. Preliminary analysis has resulted in the recommendation to consider areas with outcrops of Cambrian sediments, such as Narva, Viivikonna, Jõhvi, Võhma and Võru when selecting a construction site for the radioactive waste disposal facility. Recommendations for identification of promising geological formations have been based on the comparison between isolation properties of materials that form the geological cross-section of the sites. Materials with lower water permeability (clays and loamy clays) are considered the most promising ones since water permeability is the factor that predominantly determines the properties of the environment that can contain radionuclides and prevent the spread of radioactive contamination.

Further assessments of the possibility to arrange a disposal facility in the areas above require detailed surveys to explore geological, hydrogeological and geographical characteristics as well as social and administrative conditions within the context of arrangement of a radioactive waste disposal facility.
This section also contains the description of the areas:
Pakri peninsula where the Paldiski site is located and Sillamäe.

Data on the content of radionuclides in the groundwater for the last 7 to 14 years have been given for the Paldiski site. The concentrations of all radionuclides detected are moderately low and give indications of earlier activities on the site hosting two operating nuclear reactors.



Upper Aquifer, Groundwater contours: 2004

These additional requirements for the siting of a radioactive waste disposal facility enable a more scrupulous approach to be followed to select specific areas during further stages of surveys and justifications. Such requirements include:

- criteria of unsuitability for arrangement of a radioactive waste disposal facility;
- technical/safety criteria;
- social and economic criteria.

In order to identify what the radioactive waste disposal facility will look like, the rate of radioactive waste accumulation in 2015 has been estimated. The estimates cover both the radioactive waste currently being stored in Paldiski and the one to result from the RCs dismantling as well as the future NPP operation.

The quantities of waste to be placed for disposal depend on the preferred RCs decommissioning option to be selected.

Preliminary analysis of waste to be generated in the course of decommissioning of the reactor compartments after 50 years of storage following the shutdown of the reactors shows that, due to radionuclide decay, waste resulting from cutting of the reactor and iron-water protection tank and characterized with the highest radioactivity will be eventually referred to as intermediate-activity waste whose radionuclide composition consists of long-lived radionuclides with Ni-63 being the major one. In compliance with the IAEA GSG-1, 2014 1 classification, intermediate-level waste (ILW) that contains long-lived radionuclides needs to be placed for disposal at considerable depths ranging between tens and hundreds meters. The weight of the 346A simulator equipment is 104,067 kg that of simulator 346B - 192,340 kg. Following 50 years of storage after reactor shutdown all this equipment is contaminated with long-lived radionuclides and, consequently, belongs to ILW according to the classification in the Republic of Estonia and IAEA.

Considering uncertainties in the input data with regard to the weight of non-estimated structures and activity of the equipment we will assume that the weight of radioactive waste is 10% bigger: thus, the weight of ILW will be up to ~115,000 kg for the 346A simulator and up to ~ 210,000 kg for the 346B simulator.

General denominative information on approximate indicative volumetric characteristics of RW is presented within the Report on Task 3 "Determining the possibilities of decommissioning the reactor compartments" (Chapter 3 "Description and assessment of the waste to be generated in the course of the decommissioning works") in accordance with the concepts, technologies and waste assessment covered within the scope of Task 3.

The quantities of secondary radioactive waste to be generated in the course of decommissioning will also depend on the decommissioning option to be selected, dismantling technologies to be applied and the duration of activities. Secondary waste will comprise: work clothing, PPE, grinding media, consumables for dismantling equipment (e.g., filter cartridges, diamond grinding cup wheel, blades for reciprocating saws, abrasive discs etc.). The quantity of such waste is estimated (based on similar activities) at about 25 m^3 to 30 m^3.

Indicative total weight of radioactive waste to be generated in the course of dismantling of the RCs, irrespective of the RC decommissioning concept, is expected to reach approx. 350,000 kg, and approx. 400,000 kg if secondary waste is considered.

Depending on the decommissioning concept (A or B), the volume of radioactive waste will reach about 732 m^3 or 519 m^3 respectively.

Besides, the design of the disposal facility capacity must consider 985 m^3 of existing radioactive waste currently stored at the Paldiski site.

Also, the capacity of the disposal facility should take into account the RW streams generated in the Republic of Estonia annually and single volume waste which is expected to be generated by the year of 2039. In accordance with the estimations presented within the "National programme for radioactive waste management", the average expected streams of waste to be generated in the Republic of Estonia annually and by the year of 2039 are as follows:

- 0.27 m^3 low- and intermediate-level short-lived waste annually;
- 0.06 m^3 low- and intermediate-level long-lived waste annually;

[1]Classification of Radioactive Waste, IAEA Safety Standards Series GSG-1, 2014

- 10 m^3 cleared liquid waste annually;
- 0.4 m^3 (contaminated metal) NORM waste annually;
- 72.5 tonnes of Molycorp Silmet AS NORM waste (potential NORM waste) annually;
- 0.1 l low- and intermediate-level liquid waste annually;
- single large-volume concrete scrap from Tammiku decommissioning, 28 m^3;
- single large-volume metal contaminated with NORM waste from Molycorp Silmet AS, 200 tonnes.

The summary anticipates about 0.85 m^3 of radioactive waste to be generated in Estonia annually. As decommissioning and final disposal will start in 2039, it is expected that about 20 m^3 of radioactive waste will be generated over the period of 2016-2039.

The total quantity of conditioned radioactive waste resulting from the future NPP (AP-1000 reactor) operation and decommissioning is expected to amount to at least 15,401.5 m^3. This must be taken into account when the capacity of the disposal facility is calculated.

So, the recommended total capacity of the disposal facility should be not less than 2500 m^3 with consideration of about 9-10% reserve.

5. TASK 3 DETERMINING THE POSSIBILITIES OF DECOMMISSIONING THE REACTOR COMPARTMENTS

The scope of the work included evaluation of potential decommissioning options for the reactor compartments at the Paldiski site taking into account international experience in dismantling of reactor compartments, assessment of volume and activity levels after 50 years of storage of waste expected to be generated by dismantling of the reactor compartments and enclosures depending on decommissioning option, waste classification in accordance with the applicable IAEA safety guidelines, safety assessment of decommissioning of the reactor compartments taking into account the waste generated during work performance.

Completion of preliminary research will provide the necessary conditions to start the environmental impact assessment of the decommissioning of the reactor compartments efforts and construction of a radioactive waste storage facility. After completion of environmental impact assessment, works can be started on the design and construction of the storage facility and decommissioning of the reactor compartments.

Task 3 consisted of the following subtasks:

Assessment of Different Methods Used for Decommissioning of the Reactor Compartments

The current subtask presents potential options (concepts) for decommissioning of the reactor compartments based on the international experience available, and presents key scenarios for the reactor decommissioning, which are:

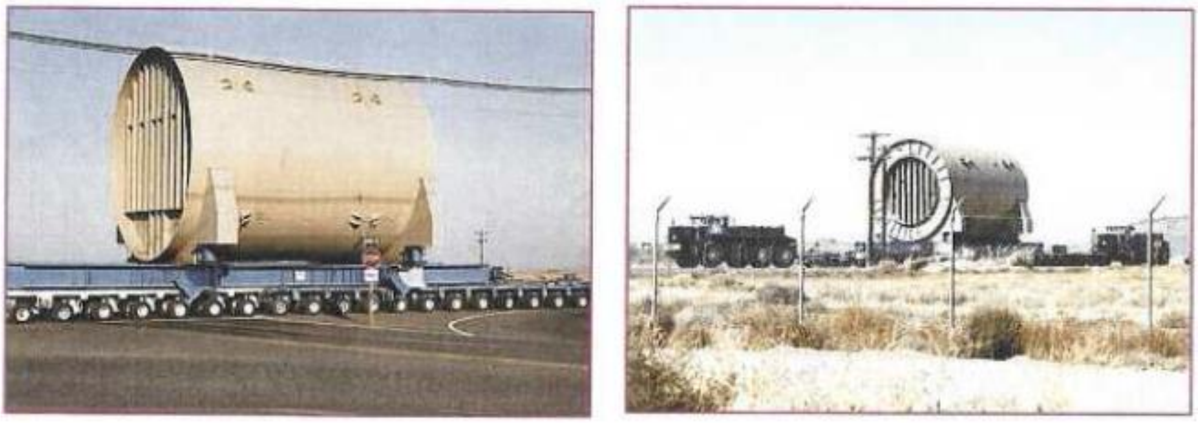
Decommissioning Concept A: local cutting of the reactor compartments into large pieces (without cutting up the reactors) with minimum liquid radioactive waste generation;
Decommissioning Concept B: local cutting of the reactor compartments into small pieces (without cutting up the reactors) with minimum liquid radioactive waste generation;
Decommissioning Concept C: in-situ disposal of the reactor compartments;
Decommissioning Concept D: disposal of RC as a whole in a newly-built near-surface radioactive waste repository located on the same site as the former Paldiski training centre.

Concepts A and B of decommissioning of the reactor compartments essentially envisage complete dismantling (taking -apart) of the reactor compartments into pieces and transport of the pieces to a radioactive waste storage facility.
The IAEA recommendations for reactor decommissioning envisage a three stage process, where:
Stage 1 requires defueling, setting of radiation shielding and monitoring points, draining of pipes and vessels, and dismantling of electrical equipment;

Stage 2 involves dismantling of equipment with low contamination, drying, sealing and restoration of primary and secondary containment barriers and then removing the reactor compartment and placing it into a storage facility for a supervised storage period of 50 years;
Stage 3 allows the dismantling, cutting of the remaining systems as well as reactor compartments and moving the waste to a disposal facility.

An overview of international experience in reactor compartment dismantling is presented, including history background, approach and the legal situation in France, the UK, the USA, Germany and Russia.

Reactor unit removal to a transport container (UK)



Reactor compartments transport to storage location (USA)

RC Long-term storage facility (Russian Federation)

CONCLUSIONS, Subtask 1

In the course of international experience review in the field of decommissioning of nuclear submarines, it became clear that the concepts and general principles of decommissioning reactor compartments (premises) are approximately the same in different countries. Two countries, the USA and Russia, have a more extensive experience in this field.

The review of the international experience and available materials shows that Russia is the leader among other countries in terms of numbers of dismantled nuclear submarines. Table 1 given below provides statistics for the state of works on the dismantled nuclear submarines in 2014.

Table 1 Statistics of the state of works on dismantled nuclear submarines in 2014

Donor country*	Disposed nuclear submarines	Nuclear submarine at the stage of disposal (order)
Russia	128	2
USA	33	1
Great Britain	4	-

* Information about France and China is missing due to lack of information.

At present, the primary concept for the nuclear submarine dismantling envisages cutting of the submarine into separate sections. Clean sections (sections that do not include reactors and reactor equipment) are subject to further cutting and utilization. Compartments, which include reactors and reactor equipment, are formed into a special section (usually three-block or one-block sections) for further long-term safe controlled storage in special facilities (land-based or floating storage). Currently, the period of long-term safe storage varies from 70 to 100 years. Taking into consideration current approach to long-term storage of the RCs, it is necessary to start preparations for further actions and, in case of non-extension of the storage, commence preparations for decommissioning and disposal of the RCs.
So far, none of the countries that possess NPS have practical experience with dismantling/disposal of the reactor compartments, being currently in long-term controlled storage.
Further management of the RCs from nuclear submarines is still in research and development stage. The two major conceptual approaches envisage extension of storage (deferred decision) or dismantling of RCs after the end of the safe storage period (immediate dismantling). The following basic operations are assumed for the latter:

- open the hull of the reactor compartment;
- retrieve the reactor and primary circuit equipment; perform cutting operations; package the reactor, steam generators and primary circuit pumps into containers;
- transfer the containers to storage/disposal;
- disposal of other non-hazardous components.

In view of the above, and taking into account that the safe storage period ends in 2039, the present report concentrates on the preliminary studies of the Paldiski RCs decommissioning with relation to the approach of the immediate dismantling (2039).

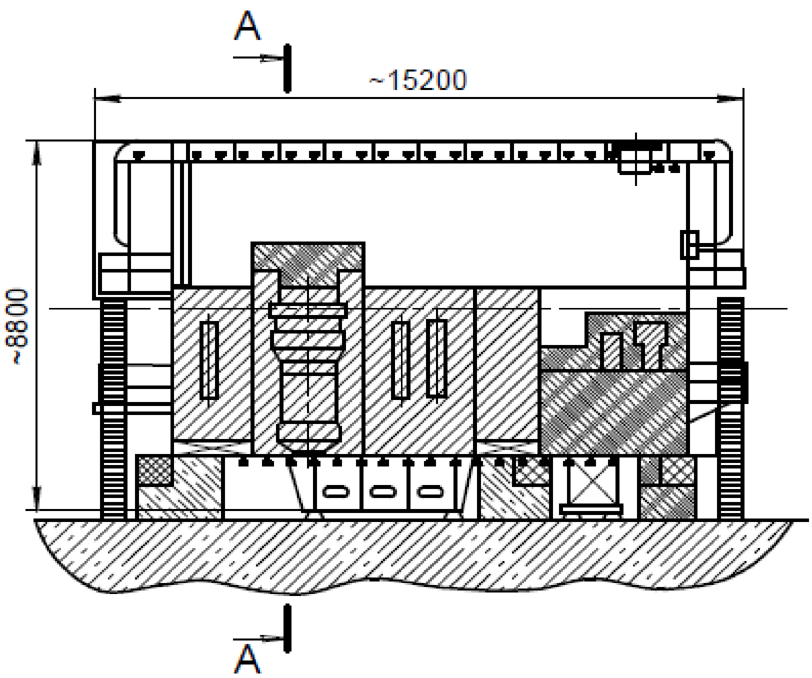
5.1. Comparative Assessment of Alternative Methods Used for Decommissioning Reactor Compartments

The subtask dealt with defining possible alternatives for the decommissioning of the reactor compartments at Paldiski:

Advantages and Disadvantages of Decommissioning Concept A: Local Cutting of Reactor Compartments Into Large Pieces, including technical analysis, cost of the equipment and radiation safety assessment;

Advantages and Disadvantages of Decommissioning Concept B: Local Cutting of Reactor Components into Small Pieces, including technical analysis, cost of the equipment and radiation safety assessment;

Advantages and Disadvantages of Decommissioning Concepts C and D: In-situ Disposal of Reactor Compartments, including technical analysis, economic analysis and radiation safety assessment;



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Reactor unit 346A

The report also provides justification of the selection of the Concept for decommissioning of the reactor compartments on the Paldiski site.

Examples of machine tools used for decommissioning (Behringer horizontal band saw)

CONCLUSIONS, Subtask 2

Various examples of technologies and equipment for RC decommissioning (including indicative estimation of the 2015 prices for some units of equipment/installations) have been reviewed. These estimates and assessments were made as an example only. All requirements to technologies, equipment and installations should be specified at the design stage as well as the cost estimate for decommissioning and corresponding equipment.

Several decommissioning concepts have been considered within the framework of the abovementioned approaches:

Concept A – local cutting of the reactor compartments into large pieces (without cutting of the reactors) with minimum liquid radioactive waste generation;

Concept B – local cutting of the reactor compartments into small pieces (without cutting of the reactors) with minimum liquid radioactive waste generation;

Concept C – in-situ disposal of the reactor compartments;

Concept D – disposal of the RCs in their entirety in a newly-built near-surface radioactive waste repository located on the same site as the former Paldiski training centre.

Concepts C and D have been considered above as alternative concepts only. Nevertheless, although they seem to be more preferable in terms of costs, dose rates and operational risks, they are characterized by the single option of the final disposal site selection due to their confinement to the Paldiski site. Also there are major factors that could be assessed as negative: safety, limited selection for disposal options and non-compliance to international requirements – these concepts are not correlated with recommendations of the IAEA in relation to radioactive waste disposal.

Selection of the final disposal facility location (at the Paldiski site or far from the site) will potentially be an important factor for the decommissioning plan, design requirements and costs. Concept A (cutting of the reactor compartments into large pieces) provides for minimization of the dose rates for the personnel as compared to Concept B. Both concepts assume that the reactor pressure vessels will be disposed of as a whole without cutting to prevent highly active radionuclides from being released into the environment. Both concepts require demolition equipment, concrete crushing, development of a special container for transportation/disposal of the reactor pressure vessels. Concepts A and B require specialized installations and equipment for mapping of sources of ionizing radiation (to a lesser extent for concept A). Compared to concept A, concept B requires more precise cutting of concrete and decontamination; and, in its turn, it provides for better radwaste management (including assumption of use of the existing containers) and safety, so it makes it possible to minimize quantities of the radwaste requiring final disposal and, correspondingly, the volume of the radwaste repository to be constructed. Among the analysed concepts of the reactor compartment decommissioning Concept B seems to be preferable, notwithstanding that it is more labour- and cost-intensive.

5.2. Development of the Concept of Decommissioning Selected as a Result of the Assessment

Development of a decommissioning concept that would be most feasible for the Paldiski site is a complex task involving technical, safety, economic and legal aspects. It is therefore very important at the conceptual stage to provide the decision-makers in Estonia with the pros and cons of possible alternatives. The subtask therefore provides an assessment of alternative methods used for decommissioning of the reactor compartments and provides fair input for the development of the concept of decommissioning selected as a result of the assessment, including the technical aspects, regulatory background, strategy and its justification, the work sequence and a preliminary schedule.

After detailed consideration and a comparative technical and economic comparison of possible options of the reactor compartment decommissioning concepts, the report defines Concept B (cutting of the reactor compartments into small pieces, but disposing of the reactor vessel uncut) as the most viable reactor compartment decommissioning option and provides an implementation strategy for it.

CONCLUSIONS, Subtask 3

1. The following was taken into consideration when the Concept of Decommissioning of the Reactor Compartments (RCs) of the Former Paldiski Military Site was developed:

- current condition of the Paldiski Site where two sarcophagi with reactor compartments inside are kept in long-term storage;
- safe condition of the two sarcophagi, the MTB and facilities inside this building, with safe condition being confirmed by radiological monitoring findings in the MTB and RC internal rooms as well as determined in the course of technical visits by Eksortus, FCNRS and Atomproyekt experts;
- plan of the Republic of Estonia to build a repository for final disposal of radioactive waste that had been accumulated and are to be generated, including radwaste resulting from dismantling of the RCs;

- plan of the Republic of Estonia with respect to final decommissioning of the hazardous radiological legacy site in Paldiski;
- experience of AS A.L.A.R.A. as an operator that ensures safe storage of the sarcophagi and with AS A.L.A.R.A. carrying out current activities associated with managing radwaste both being already in storage and arriving from companies in the Republic of Estonia;
- findings from earlier studies and assessments conducted in 2001 and 2004;
- input data submitted by AS A.L.A.R.A.;
- results of selecting RC decommissioning options (Sections 2 and 3.4 hereof);
- outcomes of technical meetings No. 1-6, two Steering Committee meetings and a technical workshop at the Ignalina NPP.

2. The Concept and sections of Task 2 and Task 3 reports under these ‘Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository’ contain the following:

- site description (refer to Task 2 report, Sections 1.1, 1.2, 1.3 and 4);
- description of the RC equipment and systems including estimated data on dose rate levels on the surface of equipment, radionuclide content (qualitative and quantitative composition) as of 2015 and the date of expiry of RC design storage period (Task 2 report Sections 1.4 to 1.6 and Task 3 report Section 4);
- RC decommissioning strategy and justification of the preferred concept;
- description of the sequence of activities and measures including site preparation for commencement of dismantling and construction of a ‘packaging workshop’;
- identification of the sequence of works associated with dismantling of the RCs, reactor systems and equipment, including their decontamination;
- description of the waste transportation procedure;
- safety in the course of RC dismantling including a list of measures and activities aiming at safety assurance as well as safety criteria;
- outstanding technical issues that might cause delays as well as measures aiming at minimising potential delays;
- assessment of technical preparedness of the Republic of Estonia for implementation of the RC decommissioning on the Paldiski Site.

3. A number of the following matters have been considered in other sections hereof and in Task 2 report, viz.:

- for potential escape of radionuclides (leaks) in the course of the dismantling of the RCs and reactor equipment;
- an indicative programme of the RC decommissioning is given;
- comparison of various decommissioning concepts including indicative costs and scope of works and estimated dose budget/person for the entire period of works are given;
- outstanding issues with respect to elaboration of regulatory framework in the Republic of Estonia are covered in Task 2 report, sections 2 and 3, and considered in the indicative programme of works.

4. Issues pertaining to technical supervision and regulation in the course of decommissioning are in the purview of the Site Operator within the licensing framework subject to current Estonian procedures.

5. This Concept is advisory in nature since it is based on indicative calculations in absence of as-built design documentation for the existing Main Technological Building and facilities inside including the sarcophagi with the RCs.

6. Following the comprehensive engineering and radiological surveys and the issue of as-built and reporting documentation the Concept needs to be updated based on realistic and actual data. The updated Concept should be submitted to the Estonian governing and regulatory bodies for agreement and approval.

7. It's recommended to start with RC decommissioning not later than in 2040 to avoid unnecessary risks. EIA was conducted during 2004-2005 to ensure safe condition of the RCs until 2040. As a result of the EIA the main technological building (where the RCs are installed) was renovated in 2005-2008. During renovation of weather-proofing of the MTB was improved, however no reinforcements were made for foundation and structures.

If storage of the RC is planned beyond 2040, a new EIA has to be conducted and the condition of MTB structures and foundation have to be studied carefully as the MTB will then have been built 80 years ago (in 1960). Far more detailed renovation works have to be conducted compared to those done in 2005-2008 starting with improvement of the foundation and basic structures. Indicative cost for EIA and renovation of the MTB is 10 million euro.

There are 2 negative scenarios related to renovation of the MTB:

1. As an outcome of EIA study it appears that renovation of the MTB foundation and basic structures doesn't ensure safety of the building. Consequently the existing MTB has to be demolished and a new shelter building has to be erected. This would cost 50 mln euro and, despite all the expenses, it would still be necessary to build a repository as storage is not a safe long-term solution;

2. As an outcome of EIA study it appears further that safe storage of the RCs is not an option as there is a risk of radioactive leakages into the environment (soil, groundwater, etc.) in the near future. It is also possible that there have been unreported radioactive leakages during operation of the reactors due to military background of the facility. In both cases further storage of the RCs is not a safe option and immediate decommissioning is required.

5.3. Description and Assessment of the Waste to be Generated in the Course of Decommissioning Works

The present subtask looked into the characterization of radioactive waste that has already accumulated at the Paldiski site and also at the waste which will be generated by the dismantling activities. The main areas dealt with in the current subtask were:

- Characteristics of Waste to be Generated During Decommissioning of Units 346A and 346B;
- Characteristics and Classification of Waste to be Generated During Dismantling;
- Characteristics of Waste Placed into the RCs for Storage Prior to Preservation of the Units;
- Characteristics of the Radioactive Waste to be generated by the Dismantling of Concrete Poured into RCs Prior to Preservation of the Units and Sarcophagi.

Also, an estimate has been made of the waste amount to be generated during decommissioning of units 346A and 346B for various decommissioning options.

Process solution options provided for management of radioactive waste generated by dismantling includes an indicative assessment of the quantitative and cost parameters of radioactive waste management for various concepts. Moreover, specific resources will have to be earmarked for the development of new casks for transfer to the disposal facility of the reactor compartment equipment after disassembling.

Indicative list of waste containing hazardous and toxic substances (other than radioactive) produced by dismantling of the reactor compartments has been produced, based mainly on the experience in the Russian Federation.

CONCLUSIONS, Subtask 4

Solid radioactive waste to be generated during decommissioning of units 346 A and 346 B can be divided into the following groups:

- waste with activity induced by reactor structures;
- waste with activity made-up by corrosion and fission products deposited on the surfaces of primary circuit structures and equipment;
- non-radioactive waste in the form of reactor compartment structures and shielding;
- waste placed into the reactor compartments for storage prior to the preservation of the units;
- waste generated by the dismantling of concrete grout used for the preservation of the reactor compartments;
- waste generated by the dismantling of sarcophagi.

Waste quantity is assessed for the period of expected decommissioning, i.e. after 50 years of cooling after reactors shut-down.

Analysis of data available demonstrates that after 50 years of storage some equipment would no longer fall into the radioactive waste category and would instead by classified as free release materials. Further cooling would not cause any significant reduction of the volume of radioactive waste.

However, the decommissioning process will yield a certain amount of toxic and hazardous materials, the management of which should also be taken into account.

Conditioned radioactive waste volume arising from decommissioning of both reactor compartments with fragmentation into small pieces will be 987 m^3.

In accordance with the classification of Estonian long-lived radioactive waste with concentration of less than 4000 Bq/g in individual waste packages and an average of 400 Bq/g for all packages, such waste may be disposed of along with the short-lived low and intermediate level radioactive waste. The method of disposal is not specified in the Estonian classification but by analogy with the IAEA documentation, the waste can be disposed of in near-surface disposal facilities. The limits for the disposal of long-lived radionuclides are set based on the safety assessment of specific repositories. Volume of waste suitable for near surface disposal is 143 m^3 for rig 346A and 194 m^3 for rig 346B.

Radioactive waste with specific activity of more than 4000 Bq/g includes reactors of rigs 346A and 346B and shielding tanks. The quantity of this waste for rig 346A is about 326 m^3 and for 346B – 324 m^3 under concept B. According to classification used in the Republic of Estonia this waste belongs to low and intermediate level long-lived radioactive waste.

The main radionuclide determining the activity of the products of corrosion after 50 years of storage is Ni-63.

According to the Estonian law and IAEA recommendations, this waste can be divided into two groups:

to be disposed of in a near-surface type facility - steam generators, pumps, etc. – about 337 m^3;

to be disposed of in a subsurface intermediate depth type facility - reactors, shielding tanks – about 650 m^3.

5.4. Decommissioning Safety Assessment taking into Account the Waste Quantities to be Generated

The aim of Subtask 5 was to make a general safety assessment of the decommissioning process also aiming at the identification of the order of magnitude of waste quantities to be generated.

Whichever option is adopted for the decommissioning of the reactor compartments, the provisions of applicable laws, codes, regulations and manuals in place with the utility organization must be observed same as IAEA guides and recommendations for radiation safety. Development of the dismantling technology must be based on observation of the commonly accepted ALARA principle and strict compliance with the applicable norms and regulations of radiation safety, as well as general industrial safety.

The decommissioning project shall foresee and be ready to deal with the basic sources and types of environmental impacts, such as emissions of radioactive gases and aerosols during cutting and dismantling procedures as well as opening of the reactor compartments and also polluted water discharges into environment. A detailed description of the sources and types of environmental impact should be carried out at the stage of development of design documentation for dismantling and final remediation of the site.

During processing operations with radioactive waste generated during decommissioning, provisions must be put in place to observe the requirements of codes and regulations to keep any releases and discharges of radioactive substances into the environment within permissible limits. To ensure this, permanent air treatment systems must be provided and an appropriate radiation monitoring system should be in place.

Provisions must also be in place for accounting and physical protection of radioactive substances and radioactive waste, as well as equipment the radiation characteristics of which make it potentially hazardous to workers (personnel), the public and the environment.

The need for and method of decontamination of all process circuits and equipment shall be determined by the results of engineering and radiological survey.

The results of the present analysis have indicated that the procedure of performing dismantling operations as well as the list of used up-to-date process equipment and adherence to the basic safety principles will enable the reactor compartment decommissioning process at Paldiski facility to be performed under quite safe conditions.

CONCLUSIONS, Subtask 5

One of the key components of a plan for decommissioning of a radiation-hazardous facility is assessment of safety of the decommissioning works.
Pursuant to the requirements and norms of the IAEA, prior to receipt of permission to decommission a facility, it is required that a document be obtained containing an assessment of safety of the decommissioning. Development of the safety assessment of the decommissioning has multiple purposes:

- justification for selection of a decommissioning strategy;
- systematic evaluation of decommissioning consequences, plan of decommissioning operations and potential emergency situations;
- documentary proof that the decommissioning process can be carried out safety and satisfies the regulatory requirements in the area of personnel and population protection;
- collection of information which can be used as a basis for assessment of safety of the intended decommissioning measures by a regulatory (controlling) body or any other organization which supervises the decommissioning project;
- application of the safety assessment results by a controlling authority to issue an official clearance or permission to conduct decommissioning works;
- determining necessary conditions for safe decommissioning work that must comply with the required safety standards.

Determination of the measures aimed at controlling the level of safety in decommissioning of a facility is one of the main conclusions of the safety assessment. The systems and components revealed during the safety assessment as having a role to play in ensuring safety must be incorporated into the program for supervision of the facility which comprises technical maintenance, inspection and compliance with safety requirements.

The indicative safety assessment of the concept was made for generalized effects on the main factors. Some factors have very low or negligible impact (earthquakes, flooding, natural fires, excessive heat or cold, snow load on roof, loss of energy supply). However some factors could have impact on safety with following results:

- hurricanes, storms, wind - highest average wind speed with 22 m/s gusts during a whirlwind that is not critical for engineering structures of the MTB. Maximum speed of 34 m/s observed during a hurricane and 38 m/s in a tornado may, in the worst case, lead to partial destruction of the roof and falling of floor deck fragments;
- lightning strike - MTB operation experience (about 50 years) shows that the designed and installed lightning protection system reliably protects the building against such atmospheric phenomena as thunderstorms;
- explosions on the site or in the vicinity - the resulting pressure would not lead to destruction of the building, but glazed windows might be affected;
- fall of an aircraft/flying object - in case of such an accident and subsequent fire, there would be no significant emission of radioactivity into the atmosphere. Any fire during dismantling of the RC will not lead to significant radioactive pollution of the atmosphere. More significant is pollution of ambient air by chemicals, including toxic ones, which are formed during combustion of cables, paints and plastic coatings, and so on.
- terrorism - an attack with small arms and light portable weapons (such as anti-tank guns) could be considered as an improbable event. Such an attack would not affect the integrity of the sarcophagi. However, at the stage of RPV dismantling some extra precautions would be advisable, e.g. enhance the site’s physical security and prevent any open source publications about possible schedule of operations and their procedure;
- fall of the reactor pressure vessel during its loading into a transport container - background radiation would significantly increase, though not so much as to prevent further work, i.e. after 50 years of storage, the dose rate from the reactor pressure vessel will be within 0.2 mSv/h;

Emergency situations following accidents were considered with following consequences:

- fire in the reactor room of an RC accompanied by burning heat - the effective radiation dose for the population at the time of radioactive cloud passage at a distance of 1.3 km (beyond the limits of the Paldiski facility) would not exceed the level of 0.011 nSv;
- due to absence of information about the exact location of the closed sources of ionizing radiation inside of RC No. 1, there exists a high probability of breaching of protective enclosure (container) of the closed sources of ionizing radiation during crushing, sawing and dismantling of the concrete cast inside of RC No. 1. In this event one-time individual exposure will not exceed 0.1 mSv;

When developing the final project for RC decommissioning, the technology of the process (strategy) for decommissioning can be changed compared to the initial decommissioning strategy and changes can be made to the scope and procedure of decommissioning works. If such changes have something to do with safety and can affect the justification of decommissioning safety, it is important that the initial assessment of safety is revised and, if necessary, appropriate amendments are made to the decommissioning plan.

6. TASK 4 DETERMINING THE POSSIBILITIES OF THE DISPOSAL OF RADIOACTIVE WASTE

The main recent historical developments that are of relevance to the issue in question was that, in 2002, the Government of the Republic of Estonia established an expert committee and tasked it with submission of proposals for preparation of a national radioactive waste management strategy. The following proposals have been made:

- The Ministry of the Environment is to be responsible for preparation of the radioactive waste management strategy and co-ordination of its implementation;
- Tammiku radioactive waste site must be decommissioned and the retrieved radioactive waste relocated to Paldiski radioactive waste storage facility;
- To ensure safe keeping of the reactor sections of Paldiski site until possibilities for dismantling of reactor parts and storage and disposal of the resulting radioactive waste are available, the reactor sarcophagi must be reinforced and improved as well as equipped with necessary monitoring and ventilation systems;
- The main building and facilities of Paldiski site must be rebuilt to smaller volume and the interim storage block located in the main building adjusted for long-term storage requirements;
- A management strategy for radioactive waste produced at the private enterprise AS Silmet must be prepared by the producer and co-ordinated with the Ministry of the Environment for provision of a corresponding activity license;
- A fund must be established for covering of the costs associated with proper management and disposal of radioactive waste created in the course of the production process.

During the period between 2005 and 2007 a number of activities have been undertaken on the site under the European Union Phare project 632.03.01 “Safe long-term storage of Paldiski sarcophagi and related dismantling activities”. The main objective of the project was to ensure safe storage of the reactor compartments and radioactive waste for a period of at least 50 years.

Part of the dismantling and decontamination works at Paldiski nuclear site is already completed. However, dismantling of the reactors will be performed in years 2040-2050. By that time Estonia should have a radioactive waste disposal facility, which could accommodate waste arising from decommissioning of the reactor compartments.

Estimated amount of the conditioned decommissioning waste is 987 m^3, depending on the decommissioning strategy. According to estimates, the amount of waste to be generated during dismantling of the reactor compartments will significantly exceed the existing storage space. Therefore, the disposal facility must be ready before commencing the decommissioning of the reactor compartments, presumably between 2037 and 2040.

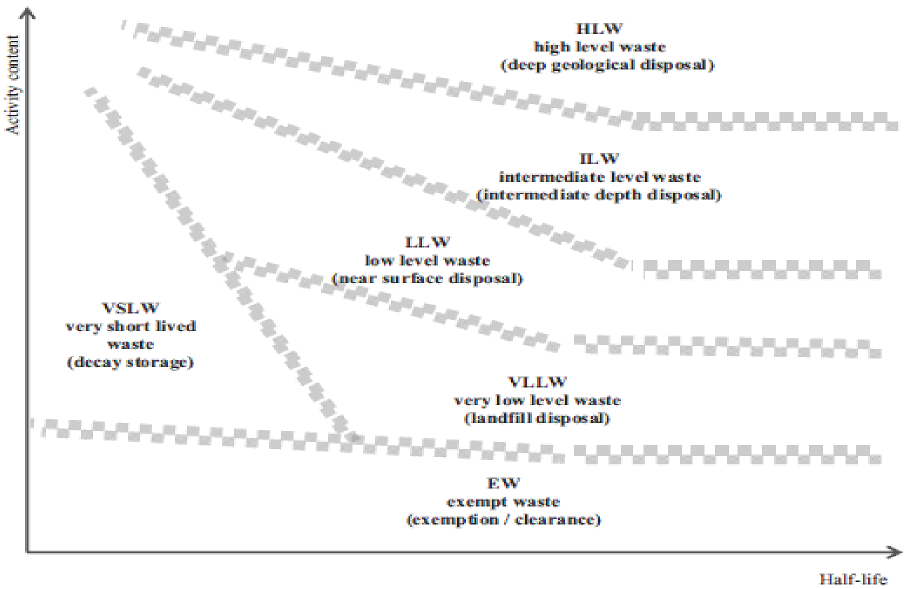
In 2015 a National Programme for Management of Radioactive Waste has been developed in response to Council Directive 2011/70/Euratom on the responsible and safe management of spent fuel and radioactive waste. It covers the following topics: overall principles and objectives of the national policy, legal and regulatory framework, responsibilities of organizations for implementation of the National Programme, waste classification system, inventory of all radioactive waste and estimation (including supporting assumptions for future estimations) of future arising, existing and planned radioactive waste management, including disposal and post closure activities, economical and financial issues. It is also important that any activities related to the future disposal facility have to follow the regulation of the Minister of Environment regarding the approved Waste Acceptance Criteria „*The Classification of Radioactive waste, the Requirements for Registration, Management and Delivery of Radioactive Waste and the Acceptance Criteria for Radioactive Waste*“

The environmental impact assessment of decommissioning of the reactor compartments will be performed based on the results of the current feasibility study. The results of the studies will be used in the process of planning of waste disposal and decision making.

6.1. Classification of disposal facilities and characteristics of each type

A number of design options for disposal facilities have been developed and implemented worldwide. They were designed to contain the waste by means of passive engineered and natural features and to isolate it from the biosphere to the extent necessitated by the associated hazard. The specific aims of waste disposal are to contain the waste, to isolate the waste from the accessible biosphere and to reduce substantially the likelihood of, and all possible consequences of, inadvertent human intrusion into the waste, to inhibit, reduce and delay the migration of radionuclides at any time from the waste to the accessible biosphere and to ensure that the amounts of radionuclides reaching the accessible biosphere due to any migration from the disposal facility are such that possible radiological consequences are acceptably low at all times.

Within a single country a number of disposal facilities of different designs may be required in order to accommodate radioactive waste of various types, like landfill disposal, near surface disposal, disposal at intermediate depth, geological and borehole disposal – all depending on the characteristics of waste to be disposed and country-specific conditions.



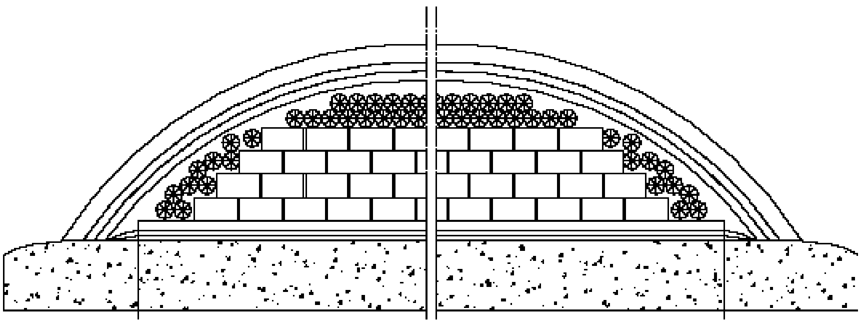
New waste classification system developed by IAEA: radioactive waste is classified considering prospective disposal options

Overview of international experience in the disposal of radioactive waste

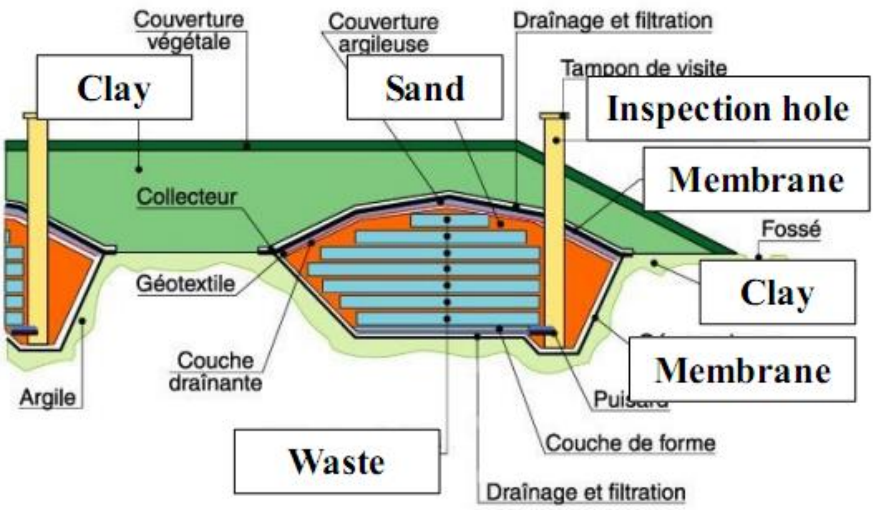
There are different approaches for radioactive waste disposal used in different countries depending on the number and type of waste generating sources. Examples are provided of approaches used in the USA, Sweden, France, Spain and Lithuania for the disposal of different types of radioactive waste.

Landfill facilities for very low-level waste:

In some countries, such as the USA, Sweden, France and Spain, specially constructed Landfills are used for disposal of VLLW. They are licensed to dispose of radioactive waste containing low concentrations of short-lived radionuclides. Summarizing experience of other countries, two main design alternatives of shallow land disposal have been analysed to select the concept of a disposal facility for Very Low Level Waste in Lithuania. One option is to dispose of the waste in a pit or trench with a tight cover put on top. This alternative is the most cost effective both with regard to construction and operation. However, site conditions should be favourable. The other alternative is to design a landfill above the ground level. In comparison with a pit landfill, the ground-based landfill is more expensive.



Approximate structure of Landfill facility in Lithuania



Schematic design of Morvilliers Landfill facility, France

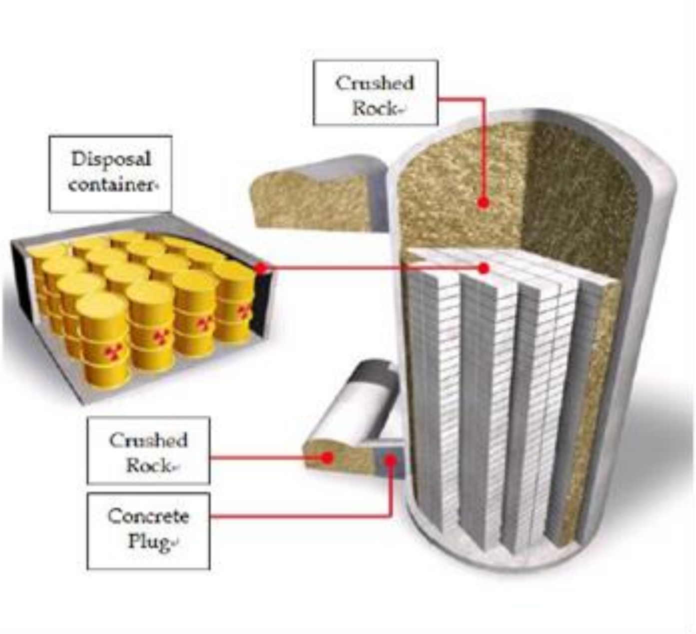
Near Surface Repositories for low and intermediate level waste (LILW):

LILW is usually disposed in facilities consisting of engineered trenches or concrete vaults constructed on the ground surface or in subsurface caverns up to a few tens of meters below ground level. Selection of this facility option mainly depends on the properties of the disposal site. The first group requires more stringent post-closure institutional control to prevent intrusion and surveillance. Near surface repositories with reinforced concrete vaults are used for waste disposal in many countries: France, Spain, Czech Republic, Japan and Slovakia.

El Cabril near surface repository, Spain

Disposal at intermediate depth

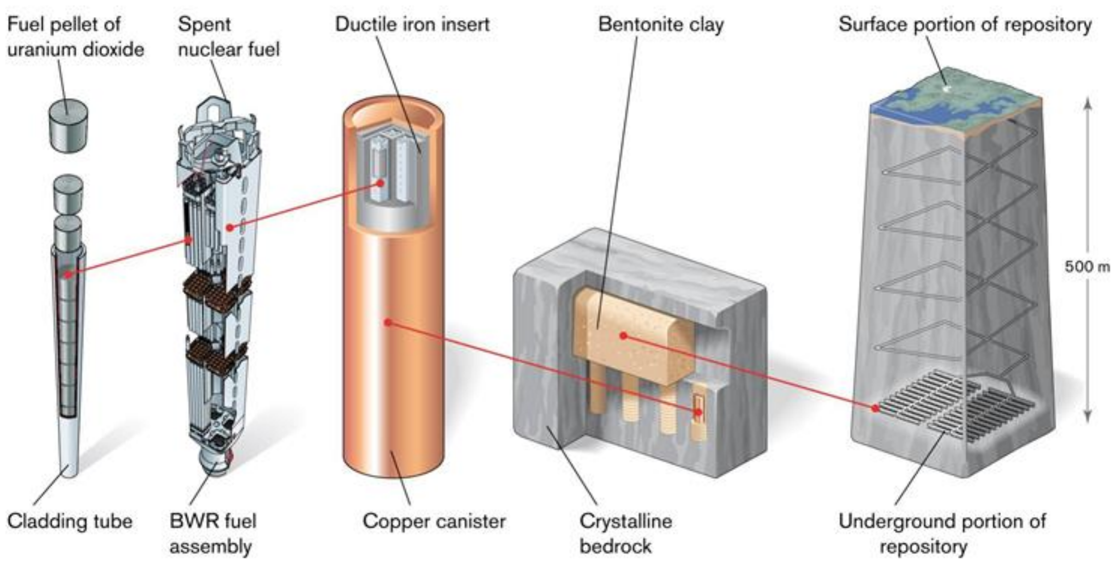
Mined cavity concept is implemented in Sweden, Finland, South Korea, Hungary and other countries. In the absence of institutional control, a depth of 30 m is considered the minimum necessary to exclude the risk of intrusion and to achieve waste isolation. This should therefore be the minimum depth required for waste that might constitute a security risk. For waste placed deeper than 30 m, isolation is primarily provided by the geosphere. The main factors to be considered in determining the depth are surface erosion and other long-scale processes.



Waste emplacement and closure plan of South-Korea repository

Deep geological disposal facilities:

Geological repositories built at least a few hundred meters below ground level have the greatest potential for ensuring the highest level of waste isolation and are considered applicable to the disposal of the most demanding categories of radioactive waste, including spent nuclear fuel, high level waste and other long-lived radioactive waste.



Swedish KBS-3 Disposal Concept for Spent Nuclear Fuel

The following conclusions can be made summarizing international waste management experience:

- Multi- barrier safety concept is commonly applied in the Near-surface Repositories. A combination of engineered and geological barriers is used for protection of the disposed waste.

- Waste emplacement in concrete vaults constructed below or above the surface represents safe solution for disposal of Short Lived LLW waste. Waste containing long-lived radionuclides are not to be disposed of in the NSR.

- There are two general NSR options: “hill” type constructed above ground water table and vaults located in water saturated zone. The first type is more vulnerable to surface erosion, other surface processes and to meteorological impact (e.g. long term draughts). However, the second is more vulnerable to flooding and bath-tubing. The “hill” type is better suitable to Estonian environmental conditions (i.e. high ground water level).

- The NSR are at risk of human intrusion. Risk reducing institution control measures consist of security, surveillance and monitoring activities as well as land use restrictions are usually foreseen for at least 300 years. Surveillance, monitoring and physical protection is rather costly.

- The surrounding geological media may play an important role in the safety case of the NSR. It should limit the impact upon the bio-sphere in case of early degradation of the engineered barriers. Because of this the repositories are constructed at properly selected sites fulfilling rather strict siting criteria.

- Despite very high cost Geological repositories are the only disposal option dedicated to highly active long- lived waste and spent nuclear fuel.

- In the current situation this disposal option is not relevant for Estonia.

- Introduction of the Geological repository may be required in the future in relation with construction of an NPP.

Requirements applicable to repositories

Safety requirements for waste disposal facilities during operation and after closure are established by the IAEA. General dose limitations are applied for the disposal facilities the effective dose for public exposure should not exceed 1 mSv per year with some exceptions for the effective dose for occupational exposure of 20 mSv in per year. There are also specific requirements for the physical protection of the site, mainly to prevent human intrusion.

The safety objective is to site, design, construct, operate and close a disposal facility so that protection after its closure is optimized, social and economic factors being taken into account. A reasonable assurance also has to be provided that doses and risks to members of the public in the long term will not exceed the dose constraints or risk constraints that were used as design criteria. Siting a radioactive waste disposal facility refers to the process of selecting a suitable location that must take into account technical and other considerations. Technical factors cover a long list: geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, human-induced events, transportation of waste, land use, population distribution and environmental protection. Another key factor is public acceptance. Technical requirements for the site belong in the concept of repository. For a shallow facility (concrete vaults of NSR or Landfill) in the vadose zone (above the ground water table), the preferred host rocks have low unsaturated moisture content providing effective drainage for water percolating through the facility and ample sorption capacity limiting the spread of radionuclides. For facilities built in the water saturated zone (trenches of NSR or IDR) the preferred environments have low intensity underground water flow (small water pressure gradients and low water conductivity of the host rocks). Geotechnical stability, seismic, tectonic and other aspects shall also be considered.

Moreover, the social and economic factors have also to be taken into account in the repository siting process.

6.2. Selection of the disposal methods most suitable for Estonia

The most relevant options for disposal of Paldiski reactor decommissioning waste are: Landfill, NSR, IDR and borehole disposal. Geological disposal option could be relevant in the future when considering construction of an NPP.

According to available estimates (Task 2 report), most of the RC dismantling waste will only insignificantly exceed clearance or exemption levels (see Table 2). This waste and part of the waste currently stored in the Paldiski storage facility could potentially be disposed of in a Landfill. The 52 ton iron-water shielding tank of the first reactor is the only component significantly exceeding clearance levels but not exceeding NSR WAC. It can be disposed of in a Near Surface Repository or Intermediate Depth Repository. Both disposal options (IDR and Landfill) fit the environmental conditions on Pakri peninsula well. Installation of an NSR could cause more problems related with long monitoring and surveillance time and risks of soil erosion or intrusion due to geological explorations.

6.3. Strategic Concept of Waste Disposal

Considering international experience, the “best international practice”, properties of the available waste and Estonian conditions the following disposal options have been identified as most suitable:

1. Intermediate Depth Repository of the **Large Diameter Shaft** type for Intermediate-Level Waste (prototypes of the facility are Russian Federation and Slovenian developments);

2. **Near- Surface Repository with reinforced concrete vaults** used for emplacement of Low- and Intermediate Level Waste (French Centre de l’Aube repository and Spanish El Cabril are prototypes of the facility);

3. **Landfill** commonly used for Very Low-Level Waste (Lithuanian Landfill design is proposed as a prototype). In Estonia Landfill can be used for disposal of waste belonging to the category of Low-Level Waste and containing minor amounts of radionuclides, i.e. not exceeding activity concentration limits to be derived for the Landfill.

The above mentioned disposal options are applicable to certain waste categories. A combination of different types of repositories is more efficient from the economic point of view. The geological repository option is included only for comparison. The proposed disposal facilities can be built on the same site or on different ones.

In the 1st case WAC have to be prepared for a Landfill. All waste exceeding the activity limits for the Landfill should be disposed of in the IDR with the rest the rest emplaced in the Landfill. Activity limits for NSR must be higher than for Landfill, therefore in the 2nd case the volume of required IDR would be smaller. In the 3rd case all available waste are to be disposed of in the same IDR. All three strategic options are suitable for a wide range of environmental conditions. Clearance principle will be applied in all investigated waste disposal options. It is assumed that waste containing radionuclide activity concentrations below the established clearance levels will be reused or disposed of in a conventional waste landfill. Comparison and ranking of the disposal options was performed together with Estonian experts. Opinion of stakeholders' representatives was considered, too. **Combination of NSR with IDR was found to be the best solution for Estonia. This option is chosen for further considerations.**

The two waste conditioning methods currently applied by A.L.A.R.A. (waste grouting with concrete in standard size containers and compressing of compressible waste in metallic drums) in principle satisfy the requirements for disposal and there is no direct need to apply additional waste conditioning methods. However, equipment used for waste cementation is rather primitive and old. Renovation of this waste treatment technique by installation of modern and more capable cementation facility is essential as much larger scale of cementation will be needed in the future (all waste in containers has to be cemented before disposal).

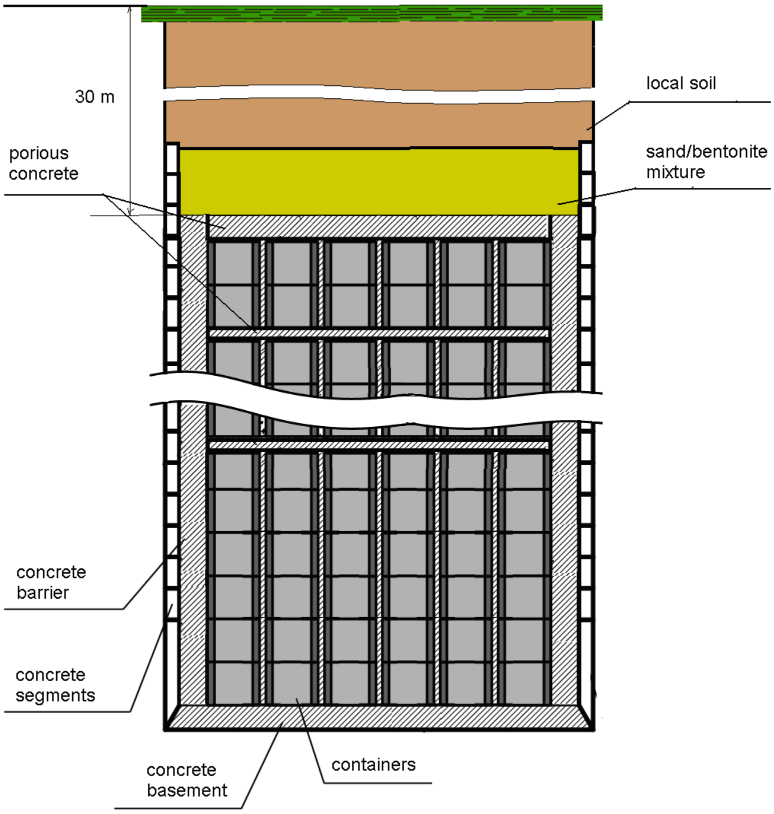
Possibility of future extension of a repository to accommodate potential future waste quantities, including eventual waste generated by an NPP was also analysed. All considered disposal facilities are modular and easily adaptable to current waste volumes. The proposed shaft-type IDR has the highest flexibility as variation of shaft geometry (diameter and depth) is possible. Extension of the repositories could be easily done by installing additional disposal modules if waste disposal activities take place at different time intervals.

From the technical point-of-view, applicable conceptual designs could be the following:

a) Shaft- type repository conceptual design

Due to high content of radioactive substances, a separate module is proposed for disposal of ILW. A shaft-type repository has been proposed with regard for the very small amount of the waste that requires intermediate depth disposal. Total depth of the proposed shaft is about 50 m while the external diameter of the borehole is 10.4 m. Waste would be disposed of at the depth between 30 and 50 meters. Shaft lining can be made of prefabricated concrete segments or "in-situ" cast concrete. The external walls are additionally lined with a layer of high quality impermeable concrete (minimum thickness of the lining is 0.5 m) functioning as an engineered barrier. The bottom slab is made of the same concrete. Porous gas permeable concrete is proposed for backfilling of voids and gaps and for the cover slab. Compacted sand/bentonite mixture is to be used for gas-permeable sealing of the disposal shaft (more information is in Annex 1). Thickness of the sand/bentonite layer is no less than 5 m. The process of shaft construction is described in

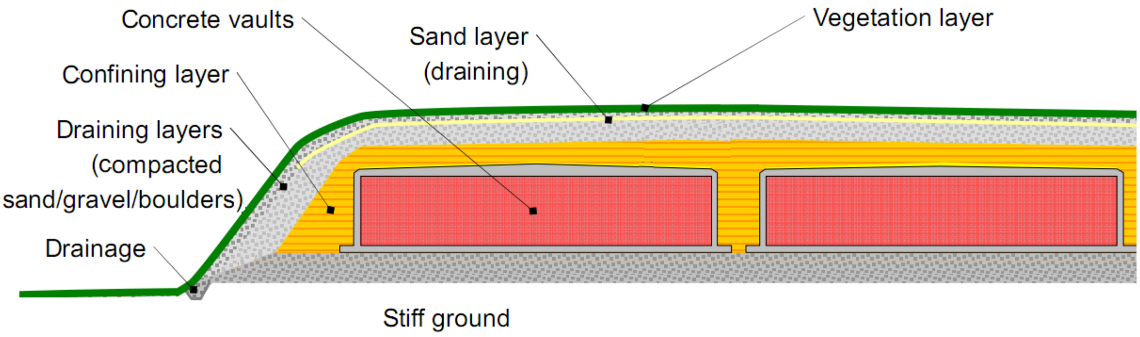
Task 4 Annex 2. The capacity of a single shaft with the abovementioned dimensions (depth of 30-50 m and shaft inner diameter ca 9.4 m) is close to 1400 m^3. This capacity is enough to accommodate all respective conditioned waste (about 900 m^3) and it also includes about 70 m^3 for contingency waste.



Schematic cross section of a closed shaft type disposal facility

b) Conceptual design of a Near Surface Repository with concrete vaults

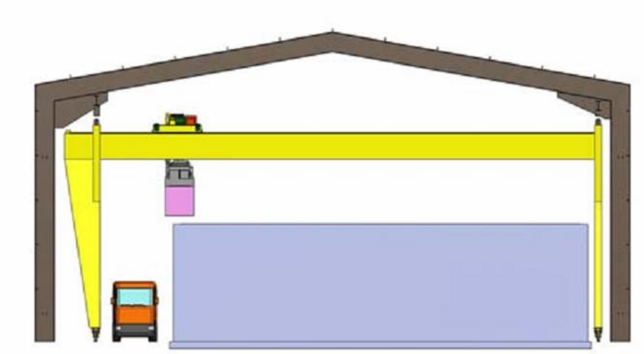
A Near Surface Repository consisting of 2 reinforced concrete vaults located on the ground surface or in an unsaturated zone is proposed for disposal of Low-Level Waste in Estonia. Proposed internal dimensions of the vaults are 15x12.5x6 m (a 1125 m^3). This capacity is enough to accommodate all suitable conditioned waste (about 2100 m^3) and it also includes about 60 m^3 for contingency waste. The conceptual design of the repository is proposed after scrutinizing available experience (France, Spain, Lithuania and other countries). The best geological environment has low saturation with moisture and good sorption characteristics which limit the spread of radionuclides and allow water to be drained effectively.



Conceptual design of Near Surface Repository: cross section of the closed repository

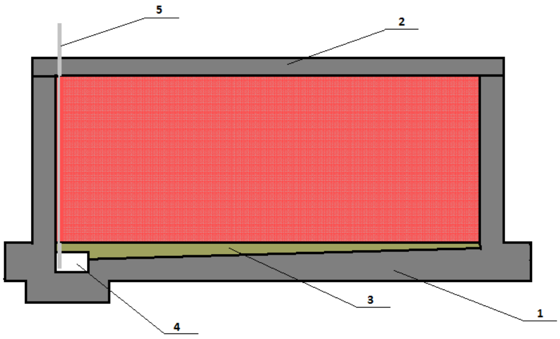
Several types of waste packages can be accepted for disposal: standard concrete or metallic containers, big size concrete containers and drums containing compacted or cemented waste. During the operational time period the repository will be equipped with a crane and covered with a stationary shelter. The shelter should minimize negative atmospheric impact and could be used for waste verification and temporary storage if needed. The shelter has to be demolished during closure of the repository.

Waste loading will be done through the top of the vault. Drums can be stacked vertically or horizontally. Voids and gaps between the containers or drums will be backfilled with cement mortar. A concrete slab will be installed above the vault with waste packages as soon as waste emplacement is finished.



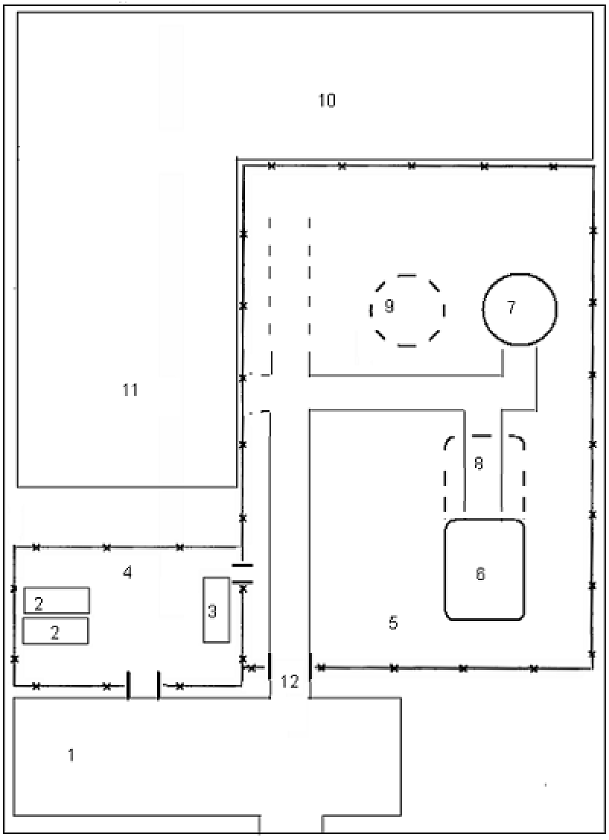
Loading of containers with waste to the Near Surface Repository vault

Radionuclide spread in the environment will be prevented by multiple passive barriers: waste matrix and container materials, concrete vaults, compacted clay barrier and natural (geological) environment. Quality and performance of all materials proposed for engineered barriers are to be assured. The clay should be either natural smectite clay or a mixture of properly graded silt, sand and gravel with 5-10% clay (bentonite). It must be compacted by a vibratory roller or plate. Indicative characteristics of the material: density above 2000 kg/m^3, hydraulic conductivity below 10^{-10} m/s, very low compressibility and high stiffness. During operation the disposal vaults will be protected by the shelter. However, small amount of water can get into the vaults. Therefore, a water collection system can be installed if needed. Seeping water will flow into a specially designed stainless steel tank. Collected water will be regularly pumped out and monitored. Water collection and monitoring can last either until installation of the repository's capping system or until the end of the active institutional control period. After that the tank has to be filled with grout and the tube must be properly sealed by concrete or bentonite.



Cross section of the disposal vault: 1 – impervious concrete bottom slab and walls, 2 – impervious concrete roof slab, 3 – water permeable concrete layer, 4 – stainless steel water monitoring tank, 5 – stainless steel water extraction tube with installed water pump

A typical layout of a generic repository based on existing best practices has been provided in the IAEA Technical Document *Technical considerations in the design of near surface disposal facilities for radioactive waste IAEA-TECDOC-1256, 2001*. The disposal facility consists of a waste disposal zone, operational zone and administrative zone. The layout of the repository may vary depending on type, characteristics and quantities of the waste and site characteristics. Taking into consideration Estonian conditions (small amount of waste from a single source) the repository can be significantly optimized. Conditions for optimization and simplification are the following: single organization responsible for waste pre-disposal management and disposal, assuming that the waste will be conditioned and fully characterized at a waste generation or storage site (except for super-heavy items), containers with waste are suitable for disposal. Also, the transportation distance would not be very long. Therefore, waste treatment, conditioning and storage would not be needed within the repository. Also, waste packages would be directly transported to the waste disposal zone without unloading and storing. In special cases waste packages can be temporally stored in shelters or returned back to Paldiski storage facility. Simple waste package verification (passport checking, visual control, gamma dose rate and contamination measurements) should be performed before emplacement of waste into the disposal modules. It is expected that mobile homes or container homes are to be used for administrative purposes, changing of clothing, contamination control and decontamination of personnel and vehicles, as well as for technical service. Also, a ground for storage of soil, sand and other materials should be allocated.



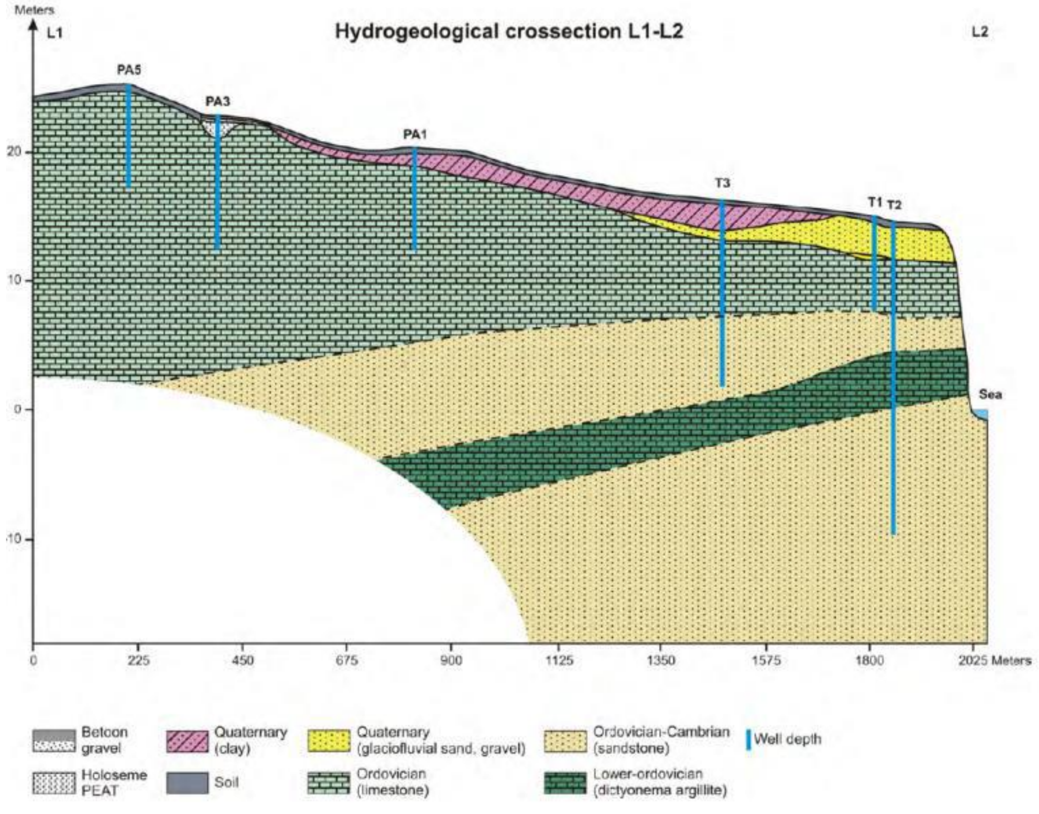
Schematic lay-out of Estonian repository: 1 - parking, 2 - administrative and other auxiliary premises, workshop, 3 – security and contamination control building, 4- administrative zone, 5 – restricted (disposal) zone, 6 – NSR modules, 7- shaft, 8 – place for additional NSR module for contingency waste, 9 – additional shaft for contingency waste, 10 and 11 – repository expansion zone and materials storage ground, 12 - main entrance to the disposal zone

According to the proposed Paldiski RC decommissioning strategy the reactors will be disposed of without dismantling. It is assumed considering the very big mass of the reactors that they will be transported to the repository without preliminary grouting (to reduce the weight during transportation). Therefore the reactors are to be grouted in appropriate containers by injecting cement grout as required by the disposal concept upon arrival to the disposal site. It is assumed that big size reinforced concrete containers will be suitable for transportation and disposal of the reactors. Considering available experience (for example Spanish) the grout is to be injected through specially designed holes in the container lid. A land plot of about 0.7 ha is needed to accommodate the IDR and Landfill modules to be used for emplacement of Paldiski decommissioning waste and other waste accumulated by that time. Additionally about 1.7 ha of land would be used as repository extension accommodating NPP waste. So, in total, minimum dimensions of the required plot are about 100x220 m.

However, **there is a number of Studies and other activities to be conducted before installation of the repository.** Radioactive waste disposal project - disposal facility life cycle - can be split into three main stages: pre-operational period, operational (waste emplacement) period and post-closure period. The pre-operational period includes facility planning, concept definition, site selection, safety assessment, design studies and construction. It also includes development of a Safety Case for safety in operation and after closure that is required in order to set the conditions of authorization, obtain the authorization and proceed with construction of the disposal facility and initial operational activities. The monitoring and testing programs that are needed to inform operational management decisions are put in place.

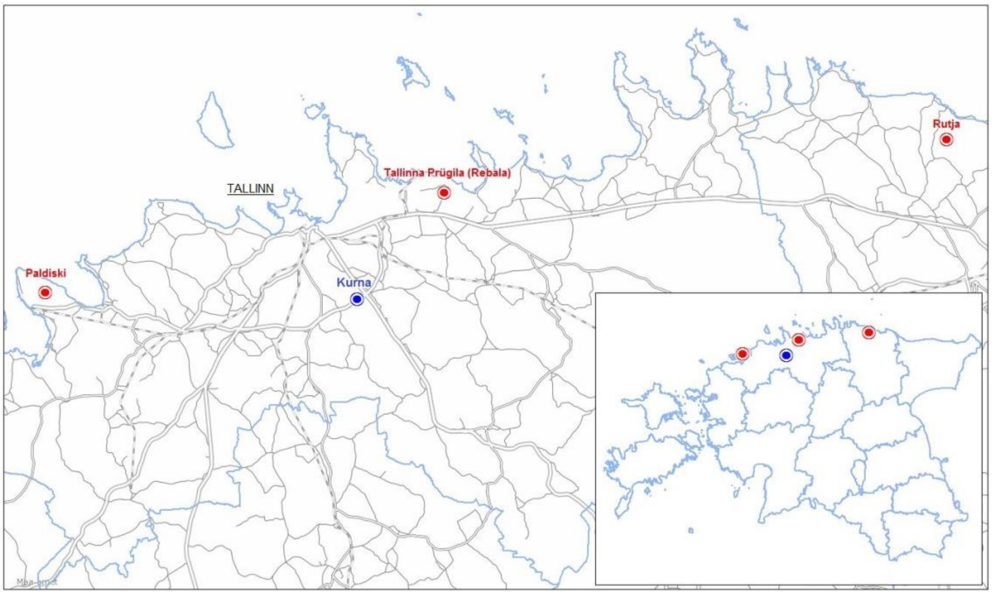
6.6 Mapping of Suitable Areas using GIS Software/Database

Six sites (Aseri, Kunda, Maardu, Paldiski, Piirsalu and Sillamäe) were analyzed for suitability to locate a waste disposal facility. All of the sites are in Northern Estonia. Suitability of the sites has been considered within the Casiopee Project. The candidate sites have demonstrated various advantages and disadvantages. Only Paldiski site located on Pakri peninsula demonstrates clear advantages: beside technical advantages discussed in previous sections it is expected that the local public's opinion regarding waste disposal will be much more positive than in other locations. Because no comprehensive siting criteria or disposal concept have been adopted, site selection is yet to be completed.



Geological cross section of Pakri peninsula

Although the sites investigated are not fully characterized yet and a lot of relevant information is still missing, a primary evaluation of suitability of the sites has been done with comparison of their advantages and disadvantages. The evaluation has qualitative character only, most of the scores are based on expert judgment, but not on quantitative results. However, the results can be used for selection of candidates for the next stage of site selection. Nevertheless, the conclusion can be made that the following sites are recommended for further investigation regarding suitability for installation of repository: Pakri peninsula (territory of Paldiski navy centre), Rutja site and Rebala site. Both Paldiski and Rutja site fits well for construction of both repository types. Kurna site is less suitable for Intermediate Depth Repository. Sillamäe site is the last one, however it can be considered too, for construction of the Intermediate Depth Repository only.



Possible sites for final disposal

It is necessary to indicate that the performed scoring and ranking of the sites is rather superficial as the sites are not well investigated and some relevant data are missing. A much more comprehensive analysis has to be done during Environment Impact Assessment.

6.7. Recommendations

Several general recommendations were made during analysis of radioactive waste disposal options in Estonia:

1. **Improvement of waste characterization system**. Good knowledge of waste inventory is a key component in preparation of a disposal facility Safety Case. In order to simplify the waste characterization process and to increase accuracy of radioactivity measurements it is recommended to characterize raw waste (before cementation). Most of long-lived radionuclides in the activated structures of reactors are beta emitters. Therefore, methods for measurement of beta and alpha radionuclides in raw waste have to be introduced;

2. **Upgrading of the waste conditioning facility**. Due to expected increase of work load, waste cementation techniques have to be improved and renewed;

3. **Development of a strategy and siting criteria for siting of the disposal facility**. Siting criteria would be an important tool during the EIA;

4. **Optimization of the waste management system and improvement of waste management effectiveness**. World wide experience in waste disposal and interdependencies between different waste management phases are to be considered.

There is also a number of additional studies and activities to be conducted which are listed in Table 13 of the report.

CONCLUSIONS

1. Construction of a repository in Estonia and disposal of radioactive waste is a feasible solution and the only sustainable option.

2. Considering radioactive waste volumes and activities arising from RC decommissioning it is obvious that storage of such waste in Paldiski interim storage is not a safe solution. Renovation of the existing interim storage or construction of a new one is only a temporary solution, considering human and environmental safety, not a long-term alternative to disposal.

3. An authority responsible for RW management and disposal in Estonia should be clearly defined to ensure internationally accepted long-term safety of radioactive waste.

4. Existing radioactive waste in Estonia is classified as LLW and ILW and there are no nuclear fuel cycle related activities and facilities in the country. As a consequence there will be neither spent nuclear fuel nor HLW present in Estonia.

5. Selected waste disposal concepts take into account the waste accumulated on the Paldiski site, waste streams related with RC decommissioning and also waste streams related to possible future nuclear power plant. The following assumptions have been made:
   - nuclear fuel will be leased and returned to the producer;
   - if any HLW arises during NPP decommissioning, it will be stored in an interim storage for decay until it can be classified as ILW or LLW.

6. Radioactivity of the most active reactor components exceeds the activity limits derived for near surface disposal of radioactive waste mainly due to risk of inadvertent human intrusion into the disposal facility. Therefore, the most active reactor components and current long-lived waste have to be disposed of at least 30 meters below ground surface to minimize the risk of intrusion.

7. A combination of underground disposal modules with disposal vaults built on the ground is the most appropriate disposal solution. Conceptually different disposal modules can be built on the same site, but can also be located on two separate sites that are better suited to different site requirements if selection of a single site suitable for both disposal options is not successful.

8. The territory adjoining the Paldiski navy centre is regarded as a potential site for construction of a waste disposal facility. Waste conditioning and transportation can be substantially simplified were the waste disposal to take place in the vicinity of the centre.

The other identified potential disposal sites are Rutja and Rebala. They are the main candidate sites to be investigated in detail during the EIA process.

9. At the current stage the waste disposal process can be defined at conceptual level only because of lack of reliable data on characteristics of the waste to be disposed of.

10. Appropriate waste characterization should be the key element of a waste management system. It is essential to confirm and verify all available estimations and assumptions on radioactivity of the waste by means of direct measurements. Measurements of radioactivity must be well planned and started at a very early stage of decommissioning activities. Highest priority should be given to assessment of long-lived beta- and alpha-emitting radionuclides defining long-term safety of the disposal facility.

11. Interdependence of various waste management steps should be considered within the radioactive waste management strategy. Waste treatment and conditioning techniques have to be selected taking into consideration the selected waste disposal option.

12. There is no information available about a shared radioactive waste disposal solution in any other countries in the world. Generally all countries have similarly to Estonia prohibited export of RW for disposal purposes (Estonian Radiation act § 61 section 10 point 6). Despite general discussions about regional disposal options there is no initiative from any country to host regional repository in the world. As establishment of any repository is very time consuming it can be assumed there will be no regional repository solution available within the next 50 years. And generally a regional solution is meant for spent fuel and HLW. For LLW and ILW every country have to develop its own disposal options.

7. TASK 5 COST OF WASTE MANAGEMENT, DECOMMISSIONING OF THE REACTOR COMPARTMENTS AND DISPOSAL

The methodology of assessing expenditures has been developed for the purposes of reactor compartment decommissioning concept “B” defined in the previous stages as having priority for implementation. Concept B provides for full dismantling of the RCs with segmentation of the compartments into small fragments (without cutting of the reactor vessels) and subsequent wide use of decontamination means with the aim of maximum reduction of RW volume subject to final disposal.

The purpose of full dismantling of the RCs is separation of radioactive materials (primarily, metal) from materials that have no contamination or are only slightly contaminate and can be decontaminated to the levels of residual activity making it possible to release these materials from radiation control. All these are attempted for maximum possible reduction of the volume of RW requiring disposal in accordance with the IAEA principles. The vessels of reactors and steam generators, which will be forwarded for disposal in special containers without fragmentation, make an exception. The following scenarios have been formulated in order to assess possible financial consequences of failure to meet the terms of the critical path (Table 1).

Cost estimations don’t include VAT and unexpected costs.

Table 1. Cost of different scenarios

Scenario name	Terms of implementation	Total costs, million euro measured in 2015 prices	Total costs, million euro measured in the prices for the appropriate years (taking into account the factor of inflation)
Basic	2016-2050	67.5	90.0
Basic pessimistic	2016-2050	73.37	-
Negative	2016-2100	117.5	-
Negative pessimistic	2040-2100	-	146.74

Basic scenario - all scheduled timeframes are accurately followed, and the actual costs in general match the costs estimated in this study.

Detailed basic scenario is presented in Table 2.

Basic pessimistic scenario – scheduled timeframes are generally followed but there is a risk of cost increase for some items (other site than Paldiski). We estimate the risk of such costs at 5 870 000 euro (~10%) in 2015 prices. These costs consist of the following:

310 000 euro - possible additional study when selecting a site for the RW repository;

260 000 euro - increase in transport costs in case of increase in the distance from the Paldiski site to the RW repository;

5 300 000 euro - purchase of additional equipment, especially a 150 t crane, in case it is impossible to restore (operational lifetime extension) the crane equipment of the MTB.

Negative scenario - involves demolition of the MTB as a consequence of its deterioration and its replacement with an umbrella arch over the reactor compartment sarcophagi and the interim RW storage facility.

We estimate that the cost of construction of such a protective structure, even if it is decided not to extend it to the sarcophagi of the RCs, will amount to at least 50 million euro, i.e. it is comparable to the cost of decommissioning of the RCs. At the same time, future generations will still have to perform the full scope of accumulated RW management and decommissioning of the RCs. In view of the above, when assessing the negative scenario, we have added 50 million euro to the cost of the basic scenario.

Negative pessimistic scenario - failure to take any measures to establish the RW management infrastructure (packaging shop and RW repository) and refusal to carry out decommissioning works past 2040. That is, it is the scenario of non-interference in the situation. This scenario is the most difficult to assess, since not taking any measures does not require any financial investments. This means that in financial terms this scenario may look more attractive than the basic one. It is not easy to assess the possible risks from accidental destruction of the MTB and the consequences of its collapse onto the sarcophagi of the RCs and interim RW storage facility. It is obvious only that mitigation of such an accident would cost multiple times more than standard dismantling of the RCs and management of accumulated waste. In addition, the no-decision scenario directly contradicts the commitments undertaken by Estonia under the Joint Convention on the Safety of Spent Fuel and RW Management in terms of not placing the burden on future generations. However, in order to show the financial estimates, we have assumed that the Negative Pessimistic scenario would be equal to the Basic Pessimistic scenario and would be implemented 50 years later. In this case, inflation processes will result in at least a twofold increase in the cost of works reaching as much as 146.74 million euro.

Table 2. Basic scenario cost assessment

No.	Measures developed in the framework of this study	Start	Finish	Total cost (2015), thousand euro
1	**Preparation and implementation of the communication strategy on the establishment of the place of disposal and the liquidation of the reactor compartments, total**	**2016**	**2050**	**490.00**

2	**EIA preparation during decommissioning the RCs, total**	**2017**	**2027**	**1 830.0**
2.1	- Engineering survey of the site facilities, including MTB structures; - Engineering survey of the RW storage facility; - Radiological survey inside the MTB; - Radiological survey of the RCs.			540.0
2.2	- Engineering survey of the sarcophagi and RCs structures; - Radiological survey of the Paldiski site; - The establishment of the equipment for “show through” concrete; - Identification of RW and radioactive sources in the concrete mass.			1 290.0
3	**EIA for the selection of the site for the repository, total**	**2017**	**2027**	**2 400.0**
3.1	Analysis of the documents from the previous surveys of the territory (if available): - Assessment of tectonic features; - Seismic analysis.			1 500.00
3.2	- Geologic-lithological composition analysis; - Relief analysis, geodetics; - Analysis of geomorphic peculiarities; - Study on hydrogeological conditions; - Hydrographic survey; - Study on the chemical composition and properties of near-surface and ground water; - Study on soils and subsoils; - Monitoring of atmospheric air; - Analysis of climatic conditions; - Environmental engineering survey (habitats and types, flora, fauna); - Social environment survey (communities, land use and land holding, economy, cultural heritage, etc.); - Noise monitoring; - Traffic and road infrastructure analysis.			900.00
4	**Application for authorizations for establishment of disposal facility, total**	**2022**	**2027**	**300**
5	**Design and construction of the repository and waste management for disposal, total**	**2027**	**2040**	**29 079.39**
5.1	- Management of accumulated RW (including disposal); - Management of RW to be annually generated (until 2040) (including disposal)			17 186.7
5.2	- Preparation of the master layout of the repository location; - Design activities including relevant expert reviews and obtaining a license for the construction.			810

5.3	- Construction and installation activities, stage 1; - Construction and installation activities, stage 2.			8 531.3
5.4	Establishment of a 'packaging shop'			2 551.39
6	**Application for authorisations for use in order to liquidate the reactor compartments and procurement of decommissioning equipment**	**2027**	**2040**	**8 809.85**
6.1	Development of the design of decommissioning the RCs			2 500
6.2	Preparatory works			1 724.35
6.3	Procurement of equipment required to decommission the RCs			4 085.5
6.4	EIA cost during decommissioning the RCs (excl. the survey)			400
6.5	Application for authorisations for use in order to liquidate the reactor compartments			100
7	**Application for authorization for use the repository and site monitoring, total**	**2039**	**2040**	**1 300**
7.1	Obtaining a license for the repository operation			100
7.2	Repository commissioning			400
7.3	Development of post-closure surveillance and monitoring programme. Revision of the post-closure Safety Assessment Report			300
7.4	Repository mothballing including designing, licensing and activities associated with the repository closure			500
8	**Decommissioning the RCs, total**	**2040**	**2050**	**23 287.13**

8.1	Management of RW resulting from decommissioning the RCs (including disposal)			15 963.9
8.2	Dismantling and disassembly of the reactor compartments			1 667.15
8.3	RW fragmentation			4 316.31
8.4	Decontamination			964.16
8.5	Dismantling of the sarcophagi			375.61
TOTAL				**67 496,37**

Possible impact of inflation on the final cost has been evaluated. The total cost of establishment of the repository, decommissioning of the RCs, etc. is estimated at 67.5 million euro (in 2015 prices). The prices of corresponding years (taking into account the factor of inflation) could be 90 million euro.

Such a sharp rise (~1.35 times) is due to the fact that the big part of the work will be carried out after 2030 that is in 15-25 years. In such a situation it is necessary to consider the organization of a fund. Capitalization of the temporarily free funds will fully or partially compensate for the inflationary rise in prices.

8. TASK 6 COMMUNICATION STRATEGY

Radioactive waste must be managed in a safe and sustainable manner. Citizens are extremely sensitive to the unknown factors raised by the effects of radioactive waste, whose management and disposal remain a complicated issue. It is clear that it is necessary to better inform the public about decommissioning and radioactive waste and, through wider consultation, improve public involvement in the decision-making process concerning management of this waste. European legislation not only encourages this provision of information and involvement in the decision-making process but actually requires it. However, this should not be seen by developers or national authorities as an imposition but as an opportunity to achieve a wider acceptance of a technology that can help to meet the higher standards of safe and sustainable environment. The basic assumption is that to achieve transparency there must be appropriate procedures enabling validation of truth, legitimacy and authenticity of any relevant claims. The issues of public acceptance heavily affect the process of radioactive waste management and disposal. In many countries great efforts are being made to overcome public perceptions that are usually negative. In some countries financial incentives have been offered to a community accepting a waste disposal site. Examples of financial incentives include monetary payments or free electricity provision. Also greater employment opportunities could be related to construction of a disposal facility. In industrialized democratic countries the public attitude of "not-in-my-backyard" can hinder the siting of all types of industrial waste facilities, including radioactive waste management sites. This causes the responsible authorities to focus great attention on societal factors during early phases of the siting and decommissioning process. In many cases, due to positive public acceptance in those locations, the repositories are being co-located at sites where nuclear facilities already exist; for example, Centre de la Manche (France), Drigg (UK), Rokkasho (Japan), Olkiluoto (Finland), Forsmark (Sweden), Mochovce (Slovakia), Visaginas (Lithuania).

8.1. Social, economic and political situation

The national structure of the country is comprised of two relatively detached communities: ethnic Estonians (about 70.0%) and a Russian-speaking community (about 25.5%), which predominantly consists of settlers from the Soviet era. These two communities can be characterised by their distinctly separate media consumption patterns. Traditionally, Estonians have been avid readers, listeners and viewers. Paldiski, the site of the closed reactors, is a town and Baltic Sea port situated on the Pakri peninsula of north-western Estonia. Paldiski is less than 50 km from Tallinn and is easily accessible. The town has about 4300 inhabitants. The majority of its residents are ethnic Russians. Paldiski has a City Council and City Government. The Chairman of the City Council is Kaupo Kallas and the Mayor is Tiit Peedu. There are two schools in Paldiski: Paldiski Gymnasium and Russian Basic School. There is a library and an internet cafe.

Today Paldiski is a centre of transit trade due to its cargo and passenger ports. A good highway and a convenient, frequent and comfortable rail service encourage this development. Paldiski harbour is ice-free during winters. The two ports, North and South, handle the traffic. Paldiski North Port could, if further developed, handle all vessels capable of entering the Baltic Sea. Great investments have been made into the two ports and their facilities with a number of new berths created. Construction of a receiving liquefied natural gas terminal near the town of Paldiski is under consideration. At present a general development plan for the next 10 years intends the following main developments: harbour development, metal works, recreation and tourism, Nature Park, logistics centre, wind farms construction. The Pakri wind farm was completed in 2004. It comprises an area of 46 hectares. Also, there is Paldiski South Harbour Industrial Park covering 21 ha close to the harbour. Since 1 January 2011 the Northern Port of Paldiski has received the status of a free economic zone. International experience shows that the communities with experience of nuclear installations have a better knowledge and understanding of the life processes of nuclear reactors, radioactive waste management and the features of its disposal. International practice shows that such communities tend to accept harmonized and consistent methodologies of decommissioning, radioactive waste management and disposal. Greater employment opportunities could be related to construction of the disposal facility. The radiation and nuclear safety policy in Estonia is mainly shaped by the Ministry of Environment. As this policy is of significant importance for the state, other ministries, authorities and the public are also involved in the process of policy-making. The Ministry of Environment establishes a radioactive waste management programme that defines the policy. The interim storage and final disposal of radioactive waste is organised by the Ministry of Economic Affairs and Communications. Therefore, it is a duty of the state to shape a policy and establish the necessary legislation and organise the management, interim storage and final disposal of waste. Public participation in respect of the drafting of certain plans and programmes relating to the environment and their amendment with regard to public participation and access to justice is defined in the Environmental Impact Assessment and Environmental Management System Act.

Existing information channels

The main information channels for accessing general public are the mass media. More and more media agents started their business in Estonia in 1991 after the country declared its independence. The newly established media groups were often bought by foreign investors. The same tendency continued in the 21st century and many media agents in Estonia are owned by foreign investors today. However the main media entities have been brought back by Estonian companies. Plenty of daily and weekly papers, magazines, seven domestic television channels and over 35 radio stations are available within the 45,000 km^2 of Estonia.

The basic information media in Estonia consist of regular media channels: print media, radio, television and internet. It is worth noting that the internet in Estonia has one of the highest penetration rates in the world. In the first quarter of 2010, 75% out of 1.36 million people in the country used the Internet according to Statistics Estonia.

Data from Public Opinion Surveys

The knowledge level had risen in Estonia since 2005. Estonians became somewhat more aware of the fact that not all radioactive waste is very dangerous. The average of correct answers concerning knowledge of radioactive waste reached 47% in Estonia (average of incorrect answers 30%, “don’t know” 23%). More than half of respondents know about radioactive waste categories. 65% of respondents said that there are several categories of radioactive waste, for example low, intermediate and high level radioactive waste. 61% of Estonians know that some radioactive waste is stored temporarily, pending a final decision on disposal. Concerning actual knowledge about ways to manage radioactive waste, 34% of the total set of answers turned out to be defined as correct, 38% were incorrect and 28% were “don’t know” replies.

The majority of Estonia's population believed that harmonized and consistent methodologies should be developed within the EU to manage radioactive waste. 89% of respondents agree with that statement.

Generalised results of the survey show that mass media are EU citizen's main source of information about nuclear issues. A large majority in Estonia (71%) mentioned television as the main source of information about nuclear energy. Television is followed by newspapers (42%), radio (39%) and the internet (34%). Mass media is the primary information source for nuclear energy issues, but journalists are not the most trusted. Looking at the survey results, we can say that 65% of people in Estonia consider the information provided by scientists to be the most trustworthy. Scientists are followed by international organisations working on uses of nuclear technology such as the International Atomic Energy Agency (23%) and national nuclear safety authorities (22%). Journalists (TV, radio, newspapers) got 18% as a trustworthy source of information.

8.2. Strategic objectives and tasks

The following objectives should be achieved in order to implement the Strategy:

1. Provide objective information to the public to ensure transparency of decommissioning and radioactive waste disposal process.

Tasks:

- Inform and educate the public about decommissioning and radioactive waste disposal;
- Evaluate public awareness about decommissioning and radioactive waste disposal.

2. Gain public acceptance of the implementation of the decommissioning and radioactive waste disposal projects.

Tasks:

- Inform the public about decommissioning and radioactive waste disposal projects in Estonia;
- Involve the public in the decision-making process;
- Demonstrate best international practice in the field of decommissioning and radioactive waste disposal;
- Monitor the level of public acceptance as decisions are taken.

The goal is public acceptance leading to approval of radioactive waste disposal and decommissioning projects from the municipality and the government. This can be achieved by informing different target groups about the necessity of solving the problems. Key persons, such as politicians at both national and regional level, can be engaged in a personal dialogue while the general public in the municipalities can be reached by organising a campaign using different mass media and other possible means.

8.3. Target groups

Any information activity has to clearly define the recipient, user or the target group for the information and shape or structure the information accordingly in order to be successful.
For the area of radioactive waste management in Estonia the following target groups have been identified:

General public of the Republic of Estonia:

- Local population at Paldiski, local Governments, Politicians;
- Public authorities, non-governmental organizations, environmental associations;
- Mass media on the national and local levels;
- Public opinion leaders, scientists;
- Young generation, students;
- International organizations as well as responsible institutions and the public in the neighbouring countries.

All target groups could be reached via these information channels:

- Internet;
- mass media (news agencies, TV, radio, newspapers, magazines);
- printed material (leaflets, booklets, brochures);
- meetings;
- study tours to countries with successful examples of radioactive waste disposal and decommissioning;
- conferences and seminars on radioactive waste management topics.

8.4. The measures to be implemented

As it is declared in the National Programme for Radioactive Waste Management, improvement of awareness related to decommissioning and radioactive waste must be ensured through various activities during the entire period of decommissioning and radioactive waste disposal process (2015–2050) in Estonia. Preparation of information materials and dissemination through multilingual (Estonian, Russian and English) information sources is important: types of waste; protection goals; decommissioning stages and the technical process; fields where 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 selection and preparation of the final disposal site; how management of radioactive waste affects surrounding residents; etc. During the period, experts engaged in decommissioning and radioactive waste management should be trained and training exercises aimed at responding to radiation emergencies related to radioactive waste should be organised and development in the field of radioactive waste management.

So far, according to the National Radiation Safety Development Plan, such development has not happened in a coordinated manner in Estonia. Participants are yet to be appointed and their interests still have to be identified. Joint interests will be mapped on the basis of the participants' needs and possibly further research or preparation of projects will also be planned on that same basis.

The main public communication principles and key messages

Three important aspects were included in the strategy: communication, education and negotiations. In the first phase communication activities are used to attain a higher level of quality in addressing the issue; the communication activities are targeted at the general public. Special care should be given primarily to informing and educating the people in order to make them understand the facts about decommissioning and radioactive waste. Educational activities are a logical and more focused sequence of the informing activities. For this reason various educational programs that consist of diverse activities should be prepared. Negotiations are a necessary part of the communication strategy as the final decision should be made by the local community.

Main information channels and tools

Diverse methods should be adopted, such as preparation of video films and various types of publications, facility visits in Estonia and other countries, direct meetings and seminars, press releases, etc. Establishing direct contact with the public at local and national levels is another method that should be adopted.

Seeking to reach as many members of different target groups as possible, various information channels should be used: internet, print media (newspapers), broadcasting media (television, radio).

The main information channel is the Internet as Estonia has one of the highest Internet penetration rates in the world. A new web site should be created and launched providing all information related to decommissioning, radioactive waste management and disposal.

Mass media is a conventional and still very important tool for reaching task audience. Press releases, seminars, technical study tours, pro-active work with mass media representatives will facilitate communication activities and stimulate genuine journalistic publicity. For that purpose a list of journalists working in the area of environment and economics for local and national level media channels have to be prepared.
The taskforce would also recommends enhancing the future site of the disposal facility with an information centre.

It could be expedient in the future to create 3D video material about the Paldiski site and radioactive waste management principles.

Authorities responsible for communication strategy implementation

The Ministry of Environment is the policy maker in the field of Radiation Safety. Currently the Ministry of Environment has a leading role in resolving radioactive waste disposal issues.

The Ministry of Economic Affairs and Communications coordinates the development of the energy sector as well as radioactive waste management, interim storage and decommissioning in Estonia. A.L.A.R.A. AS, a state-owned public limited liability company organizing radioactive waste management, operates under the Ministry (Ministry of Economic Affairs and Communications). Interim storage and final disposal of radioactive waste is organised by the Ministry of Economic Affairs and Communications, which is also responsible for the allocation of funds.

The Ministry of Economic Affairs and Communications will be responsible for the implementation of the Communication Strategy. The ministry should organize, coordinate, provide proposals for and deal with decisions regarding public information and communication. A.L.A.R.A. will work as a partner implementing the communication strategy. The Ministry of Economic Affairs and Communication will act as supervisor of all activities related to the implementation of the Communication Strategy.

Radiation safety activities are organised by the Ministry of Environment through the Environmental Inspectorate and the Environmental Board. The Ministry of Environment develops radiation safety policies and legal drafts. The Environmental Board reviews applications for radiation practice licences and licences for qualified experts, provides services ensuring radiation safety and advises the Environmental Inspectorate, which exercises supervision in all areas of environmental protection. The Ministry of Environment, the Environmental Inspectorate and the Environmental Board could act as partners implementing the Communication Strategy because they are related to the decommissioning and radioactive waste management activities.

The Ministry of Education and Research ensures organisation of educational and research activities and can cooperate as a partner in implementation of the Communication Strategy.

A governmental decision is planned for March 2016 aiming to establish responsibility for radioactive waste disposal shared by the ministries.

According to the National Programme for Radioactive Waste Management meetings intended to ensure consistency of research and development and also promote information exchange will be organised once a year on the initiative of the Ministry of Environment.

8.5. Monitoring and evaluation

While implementing the strategy, the responsible authorities must continually monitor and assess:

- Quantity and quality of information in mass media;
- Public awareness;
- Public opinion;
- Public uncertainty;
- The level of participation of scientists and non-governmental organizations in public information activities;
- Progress towards the strategic goals.

To evaluate the effectiveness of communication, public opinion polls should be performed regularly (every five years) in Estonia. The opinion of the local community in the task region is especially important. Comparison of the results from the last Eurobarometer opinion poll performed in 2008 and new results will show how effective the communication activities are. 30% of respondents in Estonia considered themselves to be well informed about radioactive waste according to the Eurobarometer survey.

8.6. Communication strategy implementation plan

This implementation plan divides activities into four main periods covering the entire thirty five years of the strategy. As planned radioactive waste disposal and decommissioning activities outlined in the National Programme for Radioactive Waste Management are divided into four periods, the Communication Strategy Implementation Plan is also divided into the same number of stages, namely:

I – Environmental Impact Assessment of the disposal facility site and Environmental Impact Assessment of decommissioning, 2017-2027;

II – Planning of the disposal facility site and application for practice licences, 2027-2037;

III – Establishment of a final disposal facility, 2037-2040;

IV – Decommissioning of the reactor compartments, 2040-2050.

The most detailed planning has been done for the first period (2017-2027) with recommendations for specific actions and first five-year (2016-2020) budget.

The plan has to be reviewed and corrected every five years. It is recommended to perform a public opinion survey once in five years and to adjust the communication plan in accordance with the opinion survey results.

The information materials should be updated in accordance with each period in relation to the main activities of the period and results of opinion polls.

Funds need to be allocated every five years in a realistic way for each of the four periods, according to the activities required and incorporated into the state budget with specific allocations for the relevant organisations, on an annual basis. The first five-year period (2016-2020) budget is 209.4 thousand Euro (VAT included).