ROSATOM FC NRS АТОМПРОЕКТ

PROJECT
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

Stage 2. Collection and analysis of the available data concerning the reactor compartments and other aspects related to legal and regulatory frameworks

T.F. Makarchuk
Head of
Export Production and Technical Department
JSC FCNRS

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Objectives of Stage 2. Collection and analysis of the available data concerning the reactor compartments and other aspects related to legal and regulatory frameworks

- **Collection and assessment of data, preparation of a list of the main parameters required to make a decision on the reactor compartments decommissioning and disposal options**
- **Collection of the available data:**
  - **- reports on previous studies;**
  - **- environmental impact assessment;**
  - **- safety assessments**
- **Assessment of the waste volumes to be generated in the course of operation and decommissioning of a future 1,000 MW nuclear power plant in the Republic of Estonia**
- **Assessment of the reliability of the data collected and sufficiency of materials for taking the decision on the reactor compartments decommissioning and disposal options**
- **Preparation of requirements and recommendations needed to implement Stages 3 and 4**
- **Assessment of the need to amend the applicable legislation of the Republic of Estonia**

Substage 2.1. Collection and analysis of the available data concerning the reactor compartments and other related aspects

- Key technical specifications of the reactor compartments
- Organization of the reactor compartments decommissioning (D) activities
- Equipment and radiological characterization of the reactor compartments
- Activities implemented to prepare the reactor compartments for long-term storage
- Radiological situation in the reactor compartments area prior to their emplacement for long-term storage
- Activities implemented at the reactor compartment sarcophagi after 1995
- Indicative analysis of radioactive waste (RW) quantities and their management in the course of operation and decommissioning of a future NPP in the Republic of Estonia

Substage 2.1. Data collection procedure

- At present the most part of design materials is not available in the archives of Russian enterprises;
- The input data of remained reporting materials, archival data, data of working documents, Technicatome reporting materials (2001) have been used;
- The data on design, weight and size characteristics of the principal equipment of power stands, on the equipment layout inside the reactor compartments (RC), on the design accumulated activity in the equipment are taken from reporting documentation of companies that designed the reactor stands, i.e. JSC Atomproekt, JSC NIKIET, JSC OKBM and CDB ME “Rubin”.

Substage 2.1. List of equipment and radiation properties of the reactor compartments. Stand 346A

Induced radionuclide activity in the principal equipment after the reactor shutdown for the cooling periods of 26 and 50 years, Bq

Radionuclide	T = 26 years			T = 50 years		
	Reactor	IWS Tank	Whole NPU	Reactor	IWS Tank	Whole NPU
^{55}Fe	8,4 E+10	4,7E+09	8,5E+10	1,96 E+08	11 E+6	1,99 E+08
^{60}Co	4,5E+12	5,0E+10	4,6E+12	1,93 E+11	2,12 E+09	1,95 E+11
^{59}Ni	1,2E+12	1,4E+10	1,2E+12	1,17 E+12	1,37 E+10	1,19 E+12
^{63}Ni	7,8E+13	9,2E+11	7,9E+13	6,66 E+13	7,81 E+11	6,73 E+13
Сумма	8,4E+13	9,9E+11	8,5E+13	6,81 E+13	7,99 E+11	6,88 E+13

Corrosion product activity in the primary circuit of the NPU for the cooling periods of 26 and 50 years, Bq

No.	Equipment	T – 26 years	T – 50 years
1	Reactor and primary circuit	1,7 E+11	6,79 E+10
2	SG	1,5 E+10	5,98 E+09
3	CM	7,5 E+09	3,09 E+08
4	ГЦЭН-146 (reactor coolant pump)	2,3 E+08	9,58 e+07
5	ВЦЭН- 147 (auxilliary circulating pump)	1,9 E+08	7,66 E+07
6	ХГЦЭН-601 (reactor coolant pump cooler)	4,3 E+08	1,77 E+08
7	ХГЦЭН-146М (reactor coolant pump cooler)	2,5 E+08	1,02 E+08
8	ХВЦЭН-147М (reactor coolant pump cooler)	9,3 E+07	3,83 E+07

Substage 2.1. List of equipment and radiation properties of the reactor compartments. Stand 346Б

Induced radionuclide activity in the principal equipment after the reactor shutdown for the cooling periods of 26 and 50 years, Bq

No.	Equipment	Radionuclide	T=26 years	T=50 years
1	Reactor	Σ	2,9 E+13	1,5 E+13
		Fe-55	3,6E+11	8,37E+08
		Co-60	5,4E+12	2,3 E+11
		Ni-59	1,5 E+11	1,5 E +11
		Ni-63	1,4 E+13	1,2 E+13
		Nb-94	1,4 E+10	1,4 E+10
		Eu-152	5,1 E+12	1,5 E+12
		Eu-154	3,3 E+12	4,8 E+11
2	Steam Generator	Σ	1,7 E+9	1,2 E+9
		Fe-55	8,1 E+7	1,9 E+5
		Co-60	3,3 E+8	1,4 E+7
		Ni-59	1,5 E+7	1,5 E+7
		Ni-63	1,3 E+9	1,1 E+9
3	Filter cooler	Σ	1,2 E+9	7,8 E+8
		Fe-55	4,7 E+7	1,1E+5
		Co-60	1,9 E+8	8,1 E+6
		Ni-59	8,5 E+6	8,5 E+6
		Ni-63	9,2 E+8	7,8 E+8
4	Pressurizer	Σ	3,6 E+7	1,9 E+7
		Fe-55	9,4 E+6	2,2 E+4
		Co-60	3,5 E+6	1,5 E+5
		Ni-59	2,3 E+5	2,3 E+5
		Ni-63	2,2 E+7	1,9 E+7
5	Ion exchange filter	Σ	1,2 E+8	7,8 E+7
		Fe-55	4,0 E+6	9,3 E+3
		Co-60	1,8 E+7	7,8 E+5
		Ni-59	8,1 E+5	8,1 E+5
		Ni-63	9,2 E+7	7,8 E+7

No.	Equipment	Radionuclide	T=26 years	T=50 years
5	Ion exchange filter	Σ	1,2 E+8	7,8 E+7
		Fe-55	4,0 E+6	9,3 E+3
		Co-60	1,8 E+7	7,8 E+5
		Ni-59	8,1 E+5	8,1 E+5
		Ni-63	9,2 E+7	7,8 E+7
6	Primary circuit pump	Σ	7,7 E+7	5,2 E+7
		Fe-55	3,2 E+6	7,4 E+3
		Co-60	1,2 E+7	5,2 E+5
		Ni-59	5,5 E+5	5,5 E+5
		Ni-63	6,1 E+7	5,2 E+7
7	Cooldown pump	Σ	1,2 E+7	8,1 E+6
		Fe-55	1,8 E+6	2,5 E+3
		Co-60	1,7 E+6	7,4 E+4
		Ni-59	9,3 E+4	9,3 E+4
		Ni-63	9,6 E+6	8,1 E+6
8	Shield tank	Σ	4,1 E+11	3,1 E+11
		Fe-55	4,1 E+10	9,5 E+7
		Co-60	1,2 E+10	5,2 E+8
		Ni-59	4,1 E+9	4,1 E+9
		Ni-63	3,5 E+11	3,0 E+11
		Nb-94	3,3 E+8	3,3 E+8
9	Concrete blocks of containment (nearest to the reactor)	Σ	2,1 E+6	1,2 E+6
		Fe-55	1,6 E+5	3,7 E+2
		Co-60	4,9 E+5	2,1 E+4
		Ni-59	1,5 E+4	1,5 E+4
		Ni-63	1,4 E+6	1,2 E+6
Whole reactor plant			2,9 E+13	1,5 E+13

Substage 2.1. Ionizing radiation sources

Ionizing radiation sources in standard containers*, including:

• transfer drums in the package weighing 1,200 kg loaded with γ-sources ^{60}Co (5 pcs.);

• paraffin container weighing 400kg loaded with ionizing radiation sources (5 pcs);

• container weighing 350kg loaded with γ-source ^{60}Co (1 pcs.)

• box weighing 60kg loaded with test and reference α- and β-sources;

• fire detectors with built-in α-sources ^{239}Pu, ^{241}Am (50pcs.)

*- The main part of sources loaded in shielding containers was placed into the horseshoe room on the ground floor comprising principal equipment of the primary circuit and in the second floor area comprising engines and pumps. These areas were grouted in concrete afterwards. There are some data that some shielding containers loaded with sources were possibly put into concrete poured on top of the reactor closure.

Substage 2.1. Waste composition

• There is also organic waste in plastic bags – rags, shoe covers, film, brushes etc. of the total weight of about 140 kg – in the waste poured with concrete in the reactor compartments.

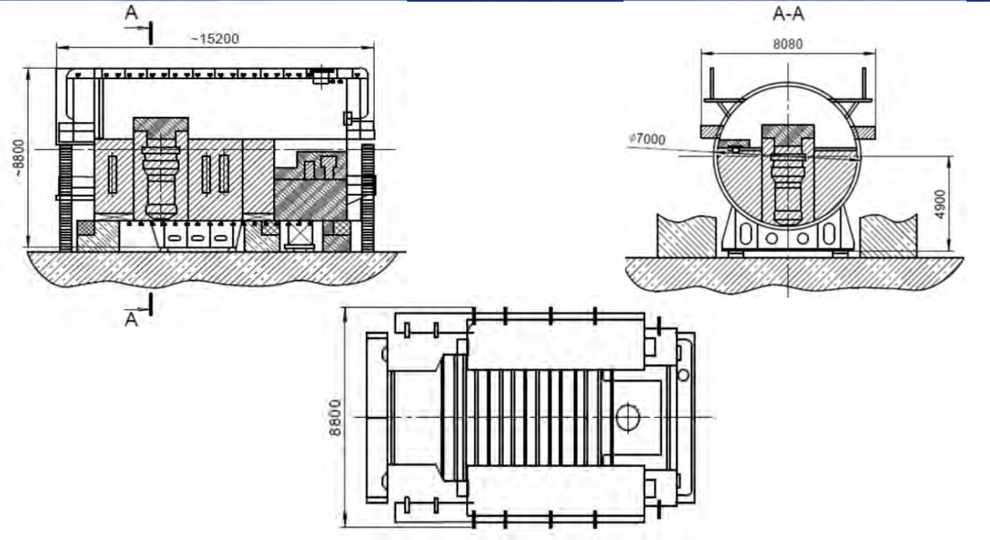
• Metal waste (tools, transfer equipment, electrical equipment etc.) is put into reactor compartment 346B. There is one air filter weighing about 200 kg from among organic waste.

• There are following volumes of unremovable water remained in equipment and pipelines of nuclear power units of stands 346A and 346B due to their design features:

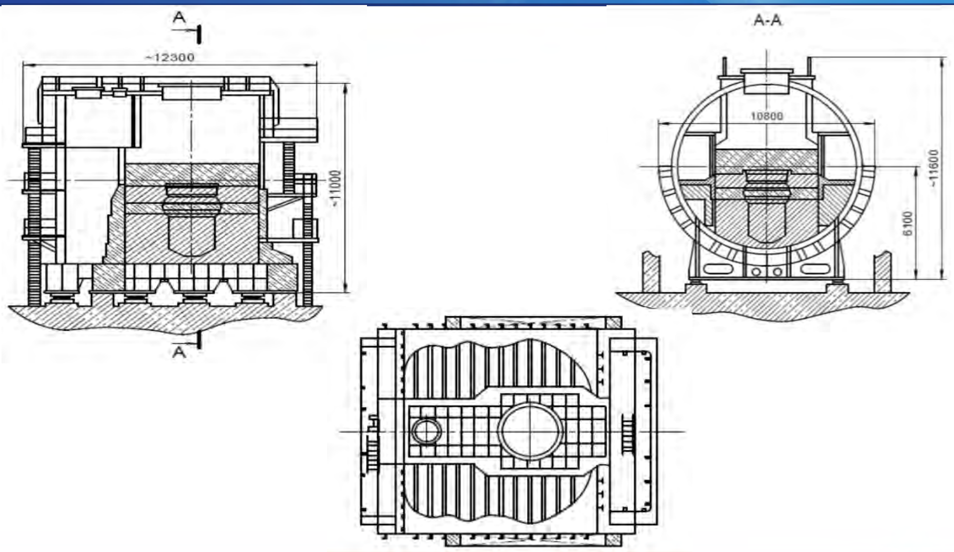
~ 1,370 l in the nuclear power unit of stand 346A (about 360 litres of this borated water is in the primary circuit);

~ 2,280 l in the nuclear power unit of stand 346B (about 600 litres of this borated water is in the primary circuit).

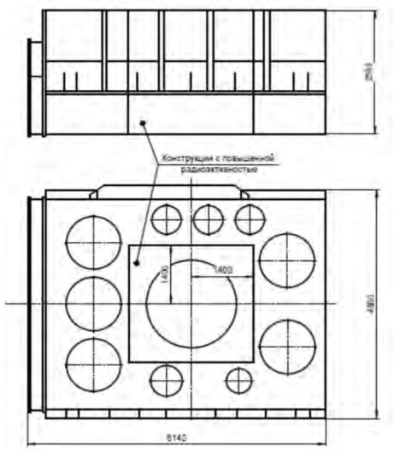
Substage 2.1. Reactor Compartment of Stand 346A

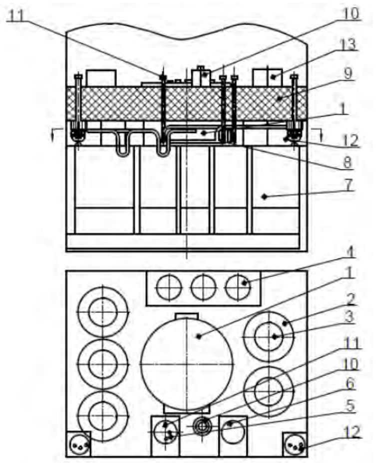


Substage 2.1. Reactor Compartment of Stand 346B



Substage 2.1. Equipment Layout





1 – reactor;
2 – steam generator;
3 – primary coolant circulating pump;
4 – primary pressurizers filter cooler;
5 – valve block;
6 – primary coolant filter;
7 – biological shielding tank;
8 – primary circuit pipelines;
9 – biological shielding;
10 – coolant pump;
11 – primary circuit valves;
12 – valve block;
13 - primary coolant circulating pump

Substage 2.1. Preliminary assessment of waste volumes of stands 346A and 346B decommissioning

Waste description	Waste weight, kg	
	Stand 346A	Stand 346B
Dismantling into large size pieces		
MLW resulted from dismantling of RC primary circuit equipment	90,000	210,000
Waste resulted from RC dismantling (releasable and non-radioactive)	765,000	740,000
Radioactive waste resulted from cutting the concrete with radwaste inside the compartments (MLW for blocks containing IRS casks, LLW, VLLW for other concrete blocks)	65,000	90,000
Waste resulted from the sarcophagi dismantling (nonradioactive)	650,000	610,000
Total radwaste	155,000	300,000
Total nonradioactive waste	1,415,000	1,350,000

Waste description	Waste weight, kg	
	Stand 346A	Stand 346B
Dismantling into small size pieces		
MLW resulted from dismantling of RC primary circuit equipment	90,000	210,000
Waste resulted from RC dismantling (releasable and non-radioactive)	765,000	740,000
Radioactive waste separated from concrete inside the compartments (MLW for blocks containing IRS casks, LLW, VLLW for other concrete blocks)	15,000	10,000
Concrete	50,000	80,000
Waste resulted from the sarcophagi dismantling (nonradioactive)	650,000	610,000
Total radwaste	105,000	220,000
Total nonradioactive waste	1,465,000	1,430,000

Waste description	Waste weight, kg	
	Stand 346A	Stand 346B
Disposal of the RCs as a whole		
Radioactive waste of MLW category in the amount of radwaste	920,000	1,040,000
Waste resulted from the sarcophagi dismantling (nonradioactive)	650,000	610,000
Total radwaste	920,000	1,040,000
Total nonradioactive waste	650,000	610,000

Substage 2.1. Indicative analysis of radwaste volumes in operation and decommissioning of NPP comprising AP-1000 power unit

Estonian national energy company "Eesti Energia" analysis showed most suitable solution for country is 1000 MW reactor. Among 1000 MW reactors due to political and financial reasons was chosen AP-1000 and Candu reactors as possible reactors for future NPP.

Pressurized water reactor AP-1000 was chosen for Paldiski project as more data of this reactor and waste volume and type was available. AP-1000 was used as prototype reactor also during preparation of work "Overview of radioactive waste management technologies and their implementation economics" ordered by Eesti Energia and compiled by independent expert Ms Merle Lust. This work focused on expenses related with waste arising from NPP and final disposal.

The indicative analysis has been performed for the conditioned (solid) waste annual volumes and volumes to be generated under decommissioning of a single unit AP-1000 with the design duration of operating life of 60 years.

Substage 2.1. Indicative analysis of radwaste volumes in operation and decommissioning of NPP comprising AP-1000 power unit

Average annual volume of conditioned (solid) radwaste under normal operation of <u>one AP-1000 power unit</u>

Description	RW class	RW volume (normal), m3
Spent ion exchange resins	MLW	7.8
Activated birch charcoal (wet)	MLW	0.6
Cartridge filter	MLW	0.2
Compactible: paper, clothes, plastic, PVC, PPE etc.	LLW	135
Non-compactible: metal parts, glass, wooden parts	LLW	6.6
Spent ion exchange resins	LLW	3.9
Activated birch charcoal (dry)	LLW	0.3
Various materials	LLW	1
Total m3/year:		155.4

Design volume of conditioned (solid) radwaste to be generated based on the decommissioning project for <u>one AP-1000 power unit</u>

RW class	Volume, m3	Weight, t
LLW	2,911.937	2,316.10
MLW	3,151.707	2,540.66
HLW	13.740	124.00
Total:	6,077.384	4,980.76

Thus the total amount of conditioned radwaste generated during the operation and decommissioning of NPP with <u>one standard AP-1000 power unit</u> shall approximately be 15 401.5 * m^3.

* - for information: *the total amount of conditioned radwaste generated during the operation and decommissioning of NPP with two VVER-1000 power units of Russian design shall be 14,290 m^3.*

Subtask 2.1. Radwaste on the Palduski site

Low and intermediate-level waste is 1032 m^3 can be considered as short-lived waste.

- 988.5 m^3 (95.7%) are from the Paldiski site (incl. Reactor sections, control rods, steam generators and filters), particularly short-lived isotopes (<30 years);
- 39.7 m^3 of waste from the storage and Tammiku used sources in shielding container - ^{137}Cs and ^{60}Co sources;
- 3.8 m^3 of waste from Tammiku repository - beta source. Most likely, it is a ^{90}Sr.

The waste is still uncharacterized, then the conclusions based on indirect estimates.

Substage 2.1. Required additional surveys

- Reactor compartment power units are radiation-hazardous facilities.
- The comprehensive engineering and radiological survey (CERS) is required to justify safety during RC decommissioning activities (including equipment dismantling)
- CERS is a set of measures required to develop RC decommissioning design and aimed at obtaining the data on the engineering and technical condition of buildings, structures and equipment, as well as on the radiation situation inside the RC, on volumetric and surface radioactive contamination of rooms and equipment, quality and volume of radioactive waste

Substage 2.1 Conclusions

- The condition of the mothballed reactor compartments is safe. Their storage period is to be over in 2045
- The data collected form the basis for the selection of the preferred option for the final decommissioning of the reactor compartments following their design storage period taking into consideration their complete dismantling and further segregation of equipment and materials into radioactive, toxic, hazardous and clean streams
- RW to be generated from the reactor compartments decommissioning shall be packaged into containers and dispatched for final disposal to a RW repository/storage facility to be constructed
- A comprehensive engineering and radiological survey is recommended aiming at practical confirmation of conceptual assumptions in the course of selecting the reactor compartments dismantling options before the design activities are commenced

Substage 2.2. Overview of international and national recommendations and legal acts on the decommissioning of reactor compartments

- Overview of the IAEA standards and guidelines for the decommissioning of nuclear and radiation hazardous facilities (NF)
  - Decommissioning of Facilities, IAEA General Safety Requirements, Part 6 (GSR Part 6), 2014
  - Safety Assessment for the Decommissioning of Facilities Using Radioactive Material, IAEA Safety Guide No. WS-G-5.2
- Overview of the European Union legal framework with respect to nuclear facilities decommissioning
  - Council Directive 2011/70/Euratom of 19 July 2011
  - Directive 2014/52/EU of 16 April 2014
  - Council Directive 96/29/Euratom of 13 May 1996
  - Commission Recommendation of 24 October 2006 (2006/851/Euratom)
- Overview of Russian recommendations and legal acts on nuclear facilities decommissioning
- Overview of the legal frameworks of the Republic of Estonia with regard to nuclear facilities decommissioning
  - Radiation Act enforced in 1 May 2004
  - Environmental Supervision Act, enforced in 06 June 2001
  - Emergency Act, enforced in 15 June 2009
  - Environmental Impact Assessment and Environmental Management System Act
  - Regulation No. 193 of 17 May 2004: Effective Dose

Substage 2.2 Conclusions

- At present there is no world experience of decommissioning the reactor units similar to the reactor compartment of stands 346A and 346B
- IAEA rules and recommendations prescribe that radiation protection needs to be ensured in the course of decommissioning
- The decommissioning strategy and radwaste management strategy shall be developed based on the EU directives
- The legal and regulatory framework of the Republic of Estonia need to be amended, and new regulatory documents need to be issued, such as resolutions by Ministries, procedures and guidelines concerning safety requirements in the course of nuclear facilities dismantling before the nuclear facilities decommissioning is commenced
- According to preliminary estimates, making the applicable legislation in the Republic of Estonia consistent with the IAEA requirements and recommendations with regard to nuclear facilities decommissioning will take from 4 to 6 years

Substage 2.3. Overview of international and national recommendations and legal acts on the final disposal of radioactive waste

- Overview of IAEA standards and recommendations on radioactive waste management prior to final disposal
  - 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
  - Predisposal Management of High Level Radioactive Waste, IAEA Safety Guide No.WS-G-2.6, 2003
- Overview of IAEA standards and recommendations on the classification and transportation of radioactive waste
  - Standards Classification of Radioactive Waste for protecting people and the environment, IAEA General Safety Guide No. GSG-1, 2009
  - Regulations for the Safe Transport of Radioactive Material, IAEA Specific Safety Requirements No.SSR-6, 2012
- Overview of IAEA standards and recommendations on radioactive waste disposal
  - 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
- Overview of the European Union legal framework with respect to radioactive waste management and transportation
  - Council Directive 2011/70/EURATOM of 19 July 2011
  - Council Directive 2013/59/EURATOM of 5 December 2013
  - Council Directive 2006/117/EURATOM of 20 November 2006

Substage 2.3. Overview of international and national recommendations and legal acts on the final disposal of radioactive waste

- **Overview of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management**
- **Overview of Russian recommendations and legal acts on final disposal of radioactive waste**
  - Federal Law On radioactive waste management and introduction of changes in some legislative acts of the Russian Federation (N190-FZ), 11.07.2011
  - Disposal of Radioactive Waste. Principles, criteria and basic safety requirements NP-055-2014
  - Near-surface disposal of radioactive waste. Safety requirements NP-069-15 etc.
- **Overview of the applicable legislation in the Republic of Estonia with regard to radioactive waste management, transportation and final disposal**
  - Radiation Act enforced in 1 May 2004
  - Environmental Supervision Act, enforced in 06 June 2001
  - Emergency Act, enforced in 15 June 2009
  - Environmental Impact Assessment and Environmental Management System Act
  - Regulation No. 193 of 17 May 2004: Effective Dose

Substage 2.3. Conclusions

- It is necessary to improve the legal framework of the Republic of Estonia as related to disposal of radioactive waste in terms of EU member mandatory compliance with recommendations and regulations of EURATOM and IAEA. It is possible to use theIAEA recommendation into national standards and regulations. To optimize the work on improvement of legal and regulatory framework it is recommended to define the range of issues based on detailed tasks by results of selection of preliminary concept of decommissioning of the Paldiski facility and the concept of creation of disposal for radioactive waste. Making decision concerning the radioactive waste disposal should be based first of all on ethical component in terms of not burdening future generations.
- **Before the nuclear facility decommissioning, some changes shall be introduced into the legislative and regulatory bases of the Republic of Estonia with issuing new normative documents such as Ministry regulations, procedures and guides related to safety insurance during the site selection, designing, construction, operation and closing the radwaste disposal facility, as those regulating acceptance criteria of conditioned radwaste for their storage and disposal.**
- **When developing new regulatory documents and amendments, the evidence base should be considered and comprehensive economic analysis carried out to confirm the availability of funds sufficient for practical implementation of standards to be accepted**

FCNRS

ENTERPRISE OF STATE ATOMIC ENERGY CORPORATION "ROSATOM"

Thank you!

phone: +7 (495) 780 74 83
e-mail: info@fcnrs.ru

Joint Stock Company Federal Center for Nuclear and Radiation Safety
www.fcnrs.ru