THE EU TAXONOMY REQUIREMENTS FOR NUCLEAR ENERGY

VVER TECHNOLOGIES AND NUCLEAR INDUSTRY INNOVATIONS

Analysis

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ROSATOM

«Nuclear power generation needs to double
if we are to reach our energy and climate goals»

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FOREWORD

In 2021, the Intergovernmental Panel on Climate Change (IPCC) stated in its report that greenhouse gas emissions at the current level would lead to disruption of environmental balance and irreversible climate change over the next decade. This fact defines the need to take urgent practical actions to combat climate change without delaying such actions until 2050-2060. At the moment, the primary issue is the lack of practical mechanisms for implementing national declarations on climate goals, which necessitates the «urgent climate actions.»

While certain circles keep debating whether nuclear energy indeed qualifies as "green" energy, it is an undeniable fact that reaching global climate goals is impossible without nuclear. The low-carbon nature of nuclear power is not disputed by international experts, nevertheless, when implementing such projects, it is necessary to pay attention to such aspects as uranium mining, water consumption, safe operation of nuclear power plants and radioactive waste management.

Experts around the world have come to a consensus that nuclear power is one of the low-carbon sources of energy and is a necessary tool needed to meet the challenges of global energy transition and the challenges of combating climate change. This view was explicitly articulated, also at the UN Climate Change Conference in Glasgow (United Kingdom) in 2021.

In order to support and promote actions aimed at combating climate change, both at the national and international levels, green regulation is being developed. Among the international standards that classify nuclear power as green, the financial taxonomy developed under the guidance of the international non-profit organization «Climate bonds initiative (CBI)» is noteworthy.

An important example of recognition of nuclear power as green on a national level is the Chinese Green Bonds Endorsed Projects Catalogue, first published in 2015. In July 2021, its updated version was approved, where nuclear power is included in the list of green projects. In September 2021, a Taxonomy of green projects was adopted in Russia – it qualifies nuclear power as green without any additional criteria.

At the beginning of 2022, the criteria for qualifying nuclear energy activities as sustainable were established by the Complementary Climate Delegated Act to the EU Taxonomy for sustainable activities (CDA, EU Taxonomy). In July 2022, after numerous discussions, these criteria were confirmed by the official bodies of Brussels; the document is subject to application from January 1, 2023.

The EU Taxonomy is the most detailed legal act regulating the sustainable activities financing, it also contains the most stringent requirements for qualifying projects as green.

Regulatory authorities, as well as representatives of financial institutions and businesses of majority of countries, including those far beyond Europe, closely monitor the application and amendment process of the EU Taxonomy.

The inclusion of nuclear in the EU Taxonomy is certainly an encouraging signal and a positive influence on the reputation of nuclear power. This fact potentially increases the interest in nuclear technologies of decision makers involved in the development of energy transition strategies – in terms of construction of new large-scale NPPs and lifetime extension of existing large-scale NPPs, as well as construction of small modular reactors in the future.

As part of the implementation of nuclear power projects and innovation developments in the industry, it is absolutely crucial to strictly comply with international and national requirements and standards. Thus, the analysis of the criteria of the CDA to the EU Taxonomy is of practical interest.

Rosatom performed analysis of the CDA requirements for nuclear energy using the example of VVER technologies, as well as a number of existing and ongoing innovative developments in the field of closing the nuclear fuel cycle.

The report also contains practical examples of projects and technological solutions from practical experience of Rosatom.

SUMMARY AND KEY FINDINGS OF THE ANALYSIS

The EU taxonomy and other green taxonomies qualifies activities as green considering its climate and ecological efficiency – that is, broader than strictly climate impact (incl. “do no significant harm” principle), but more narrow than sustainable development in the classical sense of ESG, which additionally includes social and corporate governance aspects.

The CDA to the EU Taxonomy defines criteria for qualifying nuclear energy activities as sustainable ones. It is important that nuclear energy is classified as a transitional activity named a low-carbon stable energy source, contributing to an effective and credible transition towards renewable energy sources.

Confirmation of compliance with the criteria of the EU Taxonomy is an essential factor contributing to the effective promotion of products and services in the field of nuclear power in different countries of the world. It is important to note that the CDA contains a large number of detailed criteria for nuclear technologies, some of which are not clearly defined or have no valid confirmation mechanisms.

Also, a part of the CDA criteria relates to the area of responsibility of a country at which territory the nuclear power projects are implemented – the issue of compliance with such criteria remains undetermined.

The following activities are considered in the EU Taxonomy: construction of nuclear power plants (obtaining a license until 2045), extension of the lifespan of nuclear power plants (obtaining a license until 2040) and innovation technologies (Generation IV reactors). The established criteria can be grouped into several areas: general technological requirements (key requirements for analysis), requirements for specific projects and requirements for the legislation/infrastructure (necessary to consider when evaluating potential projects).

The Rosatom experts analyzed the main criteria of the EU Taxonomy for nuclear power, which were divided into four main groups.

Confirmation of minimum level of greenhouse gas (GHG) emissions, including the following key criteria:

1. Life-cycle GHG emissions from the generation of electricity from nuclear energy are below the threshold of 100 g CO2e/kWh;

2. Life-cycle GHG emission savings are calculated using EU Recommendation or, alternatively, using ISO standards.

The requirement for GHG lower than 100 g CO2 eq/kWh is universal for all types of electricity generation in the EU Taxonomy. Nuclear power fulfills this requirement by default because its direct emissions are zero, similar to the GHG emissions generated by renewable energy sources.

According to the UN IPCC Report (2014), the levels of life-cycle GHG emissions on average are: 12 g CO2 eq/kWh for nuclear, 11 g CO2 eq/kWh for wind, 24 g CO2 eq/kWh for hydro and 48 g CO2 eq/kWh for solar, meaning that nuclear power is one of the cleanest types of energy generation. For comparison, similar indicators for gas and coal generation are 490 and 820 g of CO2 eq/kWh, respectively.

The thesis regarding the low-carbon nature of nuclear energy was explicitly voiced by experts during the preparation of the first edition of the EU Taxonomy in 2020, which read as «confirmation of the potential significant contribution of nuclear energy to the achievement of climate change mitigation goals is sufficient and clear.»[1]

Criteria of safe NPP operation include resistance to extreme external impacts (natural hazards), minimizing negative effects of NPPs on the environment, and undesirable influence on the climate goals.

The safety criteria are formulated in sufficient detail in the CDA and for the most part is presented as references to the existing EU directives and the IAEA and Western European Nuclear Regulators' Association (WENRA) standards.

Strict regulatory framework for NPP construction and operation ensure the compliance with abovementioned criteria during implementation of nuclear projects, as it also includes requirements for compliance with international standards and required reporting to supervisory national and international bodies (in particular, the Russian Federation regularly submits national reports on the implementation of its obligations for "peer review" at the IAEA meetings, according to Article 5 of the Convention on Nuclear Safety, 1994).

[1] EU Technical Expert Group on Sustainable Finance, Taxonomy Report: Technical Annex, March 2020
(EU Technical Expert Group on Sustainable Finance)

The criteria for nuclear fuel cycle (NFC) include the concept of accident-tolerant fuel, as well as the aim of closing the nuclear fuel cycle and minimization of radioactive waste production within the nuclear fuel cycle (transition to Generation IV reactors).

The CDA requirement for the transition to the use of accident-tolerant fuel is the most controversial in the professional community due to the lack of a single definition of an accident-tolerant fuel or detailed requirements for this technology. Accident-tolerant fuel is commonly understood as accident-resistant nuclear fuel. Such fuel must remain operational not only under normal conditions, but also in the conditions of loss-of-coolant accidents.

Three main approaches to the ATF development across the globe are:

1. advanced coating of fuel pellets,

2. advanced coating of fuel cladding and

3. replacement of uranium dioxide fuel with silicide and/or nitride one.

Experts agree that full-scale technological or even regulatory readiness for the use of accident tolerant fuel is not achievable by 2025 in any of these areas, as required by the CDA. In addition, along with the development of accident-tolerant fuel technologies, a technological solution for its safe reprocessing and disposal must be provided.

Without further elaboration of backend issues, there is a risk that this type of fuel will not fully comply with the principles of sustainable development in terms of “do no significant harm” principle.

In general, given the challenging nature and complexity of these issues, the requirements of the CDA to the EU Taxonomy in the field of accident-tolerant fuels are likely to be elaborated, including realistic time of its application.

There are certain difficulties with the CDA criteria interpretation in the field of closing the nuclear fuel cycle, as the definitions of spent nuclear fuel and radioactive waste are also not unified. In some of the EU member states, spent nuclear fuel is considered to be a resource, what implies the possibility of its reprocessing.

In a number of countries, due to the lack of reprocessing technologies, spent nuclear fuel is qualified as radioactive waste and belongs to storage. EU documents allow the classification of spent nuclear fuel both as recyclable products and as radioactive waste, which makes it difficult to apply the CDA requirements.

As Rosatom has spent nuclear fuel reprocessing technologies, Russian legal framework, unambiguously qualifies spent nuclear fuel as a resource, which corresponds to the CDA requirement of transition to a closed-cycle economy.

The criteria for the back-end of the nuclear fuel cycle are related to the radioactive waste management and NPP decommissioning. Consideration of the back-end issues is a necessary condition for the safety of the environment, human life and health, as well as for the "do no significant harm" principle.

As regards handling radioactive waste and decommissioning, the CDA criteria relate mainly to the national infrastructure, that is, the infrastructure of the country where the NPP project is to be implemented, including the requirements for the financial reserves for the efficient decommissioning of nuclear facilities.

One of the most important requirements is the minimization of radioactive waste production within the nuclear fuel cycle using the best available technologies – that is, in fact, the transition to closing the nuclear fuel cycle.

Taking into account the historical regulatory and technological autonomy of the nuclear industry, this task presents a certain challenge due to the need for detailed analysis of relevant requirements, calculations and justifications, detailed reports for regulatory and qualifying bodies.

GENERAL INFORMATION ON THE EU TAXONOMY REGULATION AND THE COMPLEMENTARY CLIMATE DELEGATED ACT TO IT

Regulation of the European Parliament and of the Council of the European Union 2020/852 of 18 June 2020 on the establishment of a framework for the promotion of sustainable finance (EU Taxonomy) is a regulatory document establishing economic activities that contribute to archiving environmental objectives.

Aiming at facilitating sustainable investment, the document defines the criteria, which qualify energy projects as environmentally sustainable activities. The document had been developed since 2018. The EU Taxonomy was officially published on June 22, 2020 and entered into force on July 12, 2020.

The EU Taxonomy is a key legislative act aimed at promoting the European Green Deal by stimulating investment in green projects. The document defines the criteria for green and sustainable projects with positive impact on climate, as well as the procedure of compliance with these criteria.

The EU Taxonomy establishes six environmental objectives:

1. Climate change mitigation;

2. Climate change adaptation;

3. The sustainable use and protection of water and marine resources;

4. The transition to a circular economy;

5. Pollution prevention and control;

6. The protection and restoration of biodiversity and ecosystems.

The EU taxonomy provides for three types of activities: low-carbon activities (Article 10(1)), transitional activities (Article 10 (2)) and enabling activities (Article 16). All these activities should contribute to achieving the goals of the European Green Deal: to reduce the impact on the environment by 2030 and by 2050.

An important distinguishing prerequisite for transitional activities is the mandatory requirement to disclose information about participation in transitional energy within the framework of non-financial reporting (Article 8). Also for transitional and enabling activities, the additional criteria for qualifying as sustainable activities are specified; the effectiveness of such criteria is evaluated. For nuclear power, the additional criteria are specified in the Complementary Climate Delegated Act to the EU Taxonomy.

When the EU Taxonomy was under development, issue of the inclusion of nuclear energy in it could not be resolved at the time. It was decided to conduct an additional scientific research on the compliance of nuclear energy with the «do no significant harm» principle) and with other environmental goals.

The decision was postponed until the development of supplements to the EU Taxonomy (complimentary delegated acts).

The corresponding study was conducted in April 2021 by the Joint Research Center, which came to the following conclusion: «The analyses did not reveal any science-based evidence that nuclear energy does more harm to human health or to the environment than other electricity production technologies already included in the Taxonomy as activities supporting climate change mitigation.»[2]

The decision-making procedure of supplementing acts to the EU Taxonomy adoption requires the approval of two EU legislative bodies: The European Parliament and the EU Council. The European Parliament and the EU Council did not countervote within the established time limit. Thereby, the CDA was approved and officially published on July 15, 2022. The document is subject to application from January 1, 2023.

The CDA defines the criteria for qualifying gas and nuclear power projects as sustainable. It is important that both sources are classified as transitional activities and defined as low-carbon stable base load energy sources contributing to an effective transition to renewable energy sources. Transitional nature is determined by the limitation of application period: for nuclear power it is obtaining a license for the new NPP construction before 2045 and for lifetime extension of existing NPP before 2040.

[2] Joint research center of the EU Commission, Technical assessment of nuclear energy with respect to the ‘do no significant harm’ criteria of Regulation (EU) 2020/852, April 2021
(Technical assessment of nuclear energy with respect to the DNSH)

In terms of nuclear power projects, the CDA considers three areas:

1. Pre-commercial stages of advanced technologies to produce energy from nuclear processes with minimal waste from the fuel cycle (reactors of generation IV);

2. Construction and safe operation of new nuclear power plants, for the generation of electricity or heat, including for hydrogen production, using best-available technologies (BAT);

3. Electricity generation from nuclear energy in existing installations (modification of existing nuclear installations for the purposes of extension).

The CDA criteria for nuclear energy contain references to documents of European legislation, Euratom regulatory documents, standards and recommendations of the IAEA and WENRA. The criteria can be provisionally divided into requirements for the legislation and infrastructure of the country operating NPP, general technological requirements and requirements for specific projects.

The CDA criteria for nuclear power can be divided into four groups:

1. Confirmation of the minimum level of greenhouse gas emissions, including the threshold values of CO2-eq emissions, calculation methods and their verification (the maximum value is 100 g of CO2–eq./kWh throughout the entire lifecycle);

2. Safety at the operational stage, including requirements for assessing the safety of nuclear power plants (resistance to extreme external impacts and absence of negative environmental impact);

3. Efficiency of the nuclear fuel cycle, including requirements of accident tolerant fuel, aiming at closing the nuclear fuel cycle and minimal formation of radioactive waste;

4. Safety and effective management of back-end of the nuclear fuel cycle, including the requirements for radioactive waste management and NPP decommissioning solutions.

LEGAL ASPECTS OF THE APPLICATION OF THE COMPLEMENTARY CLIMATE DELEGATED ACT TO THE EU TAXONOMY REGULATION

Regarding the assumption of obligations to comply with the CDA requirements or the absence of such confirmation when signing the contract, it should be pointed out that currently not all relevant CDA criteria are clearly defined; interpretation of these criteria may differ between vendor and customer.

Thus, there is no legal certainty and the risks of the vendor or the customer obligation default will increase. Until there is certainty in the interpretation of the CDA criteria, their inclusion in the contract is associated with significant risks.

The EU Taxonomy is a legislative act of direct effect and is binding to all EU Member States; the document has primacy over the national legislation of the EU Member States. The EU Taxonomy is the starting point for the future adoption of the legislation by the EU Member States in order to support environmentally sustainable economic activity.

Currently, the EU Taxonomy does not define the obligation to invest in a certain type of activity, including for EU Member States, nor does it establish investment bans. However, the EU Taxonomy conforms to the long-term low-carbon development strategies and specific plans within the framework of European Green Deal.

The objective and purpose of the EU Taxonomy is to establish criteria that determine whether economic activity is environmentally sustainable in order to evaluate investments in projects.

The criteria of environmental sustainability of investments is mandatory for application in order to:

1. develop in the EU and EU Member States legal acts regulating activities of financial market participants or issuers of environmentally sustainable financial products and corporate bonds;

2. establish requirements for financial market participants to issue financial instruments;

3. establish requirements for non-financial reporting.

Compliance with the criteria for qualifying an activity as environmentally sustainable is required at the stage of attracting investments or disclosing information about such activity. The EU Taxonomy does not establish a specific person responsible for ensuring compliance with the criteria (supplier, customer).

It is important to emphasize that the technical criteria of sustainability of nuclear power projects should reflect the highest standards of nuclear and radiation safety and radioactive waste management.

The text of the CDA mostly contains not new requirements, but references to the requirements and standards of the IAEA, WENRA and EU directives. From this point of view, the CDA is not a fundamentally new document, but rather a comprehensive set of existing norms and requirements.

The preamble of the CDA states that for meeting the goals of the document and the highest possible regard to the principles and requirements of the Euratom legislation, including the nuclear safety objective, investments considered should be subject to an opinion from the European Commission.

The European Commission's opinion and dedicated recommendations are mandatory regardless of whether its notification on investments in nuclear power is required (provided for in Article 41 of the Euratom Treaty of 1957).

The procedure of the European Commission's notification and development of an appropriate conclusion on the compliance of the project with technical criteria is an addition to the practice of reviewing and approving NPP projects, as it goes beyond the national comprehensive project review.

LEVEL OF GREENHOUSE GAS EMISSIONS FROM NPP

KEY CONCLUSIONS

The low-carbon nature of nuclear energy is not disputed by international experts and is unlikely to be challenged as part of the verification of compliance with the criteria of the EU Taxonomy. The potential significant contribution of nuclear energy to achieving climate goals was directly stated in the technical report to the EU Taxonomy back in 2020.[3]

The CDA establishes a requirement to not exceed greenhouse gas emissions over the entire life cycle of nuclear energy generation of 100 g of CO2-eq/kWh, but does not define a specific procedure for confirming the minimum level of CO2-eq emissions, or a mechanism for obtaining independent verification.

However, with a comprehensive assessment of a specific project, it may be necessary to provide a calculation for the facility at later stages of the project implementation. In 2022, Rosatom State Corporation is planning to develop a unified industry methodology for calculating greenhouse gases in accordance with international standards for its subsequent application for all its projects, including the construction of nuclear power plants abroad.

[3] EU Technical Expert Group on Sustainable Finance, Taxonomy Report: Technical Annex, March 2020 (EU Technical (Expert Group on Sustainable Finance)

One of the groups of CDA criteria is the confirmation of the minimum level of CO2-eq emissions, including the limit values of greenhouse gas emissions, the calculation methodology and their verification. The key criteria set out in the CDA are:

1. Life-cycle greenhouse gas (GHG) emissions from the generation of electricity from nuclear energy are below the threshold of 100 g CO2e/kWh;

2. Life-cycle GHG emission savings are calculated using Recommendation 2013/179/EU or, alternatively, using ISO 14067:2018 or ISO 14064-1:2018.

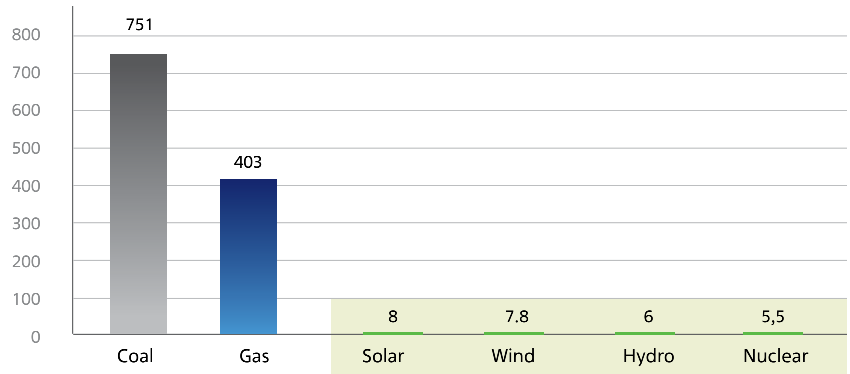
Nuclear power is a low-carbon source of generation and has a carbon footprint comparable to the carbon footprint of renewable energy sources. There are two classic scientific studies providing guidance for the international community.

Both studies confirm the low-carbon nature of nuclear power, despite the distinction of particular values. The differences in the data are explained by the fact that the figures were obtained based on the analysis of various facilities, taking into account the research objects, types of technologies and geographical differences.

IPCC studies on lifecycle greenhouse gas emissions by generation types were conducted in 2014.[4] They confirm the low figures of greenhouse gas emissions for nuclear power: the average figures are 12 g of CO2-eq/kWh for nuclear power at 11 g CO2-eq/kWh for wind and 24 g CO2-eq/kWh for hydropower, respectively.

[4] Intergovernmental Panel on Climate Change, Fifth Assessment Report “Climate Change 2014: Mitigation of Climate Change”, Annex III: Technology-specific cost and performance parameters, 2014 (IPCC Report)

Greenhouse gas emissions (lower value on the lifecycle, for nuclear energy – average value, g CO2-eq/kWh), UNECE data



In October 2021, the United Nations Economic Commission for Europe (UNECE) published a study[5] according to which greenhouse gas emissions from the lifecycle of NPP are the lowest in comparison with other types of generation (the average value for NPP is 5.5 g CO2-eq/kWh, at the lower limit of hydropower – 6 g of CO2-eq/kWh and the lower limit of wind power – 7.8 g CO2-eq/kWh).

In the structure of the carbon footprint of nuclear energy (specific emissions per unit of energy produced), the major part of emissions belongs to stages not directly related to the operation of NPP – the largest share is accounted for by the stages of NPP construction (including the construction of network infrastructure) and decommissioning, as well as uranium mining and enrichment.[6]

[5] United Nations Economic Commission for Europe, Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources, 2021 (UNECE Report); Rosatom participated in the study

[6] Vattenfall, EPD of Electricity from Vattenfall Nordic NNP, 2019
https://api.environdec.com/api/v1/EPDLibrary/Files/edd6ae95-c679-42c1-98c7-b5818d841c5b/Data

SAFETY OF NPP OPERATION

KEY CONCLUSIONS

Nuclear industry has one of the most stringent systems of safety standards in the world, which are established by the IAEA and enshrined in the national legislation of the countries implementing nuclear power projects. The nuclear safety regulation system determines, among other things, the procedure for the construction, operation and other stages of the life-cycle of NPP, the management of spent nuclear fuel and radioactive waste.

Modern standards of operational safety of NPP were formulated, among other things, on the basis of the historical experience of operating NPPs with thermal reactors of the first generations. The operational safety of modern nuclear power is appropriate for the existing scale of its use, provided that the existing nuclear power units are gradually replaced by reactors of generation III and next generations.

Nowadays, generation I and II reactors are technologically obsolete; they are no longer being built and are being gradually decommissioned. The first generation III reactors appeared in Japan – ABWR reactors at power units No. 6 and 7 of the Kashiwazaki-Kariwa NPP in 1996 and 1997.

In 2016, the first generation III+ reactor (VVER-1200 at Novovoronezh NPP-2) was commissioned in Russia. The main advantage of generation III+ reactors is the introduction of passive safety systems into the reactor design, which appeared after the events at the Fukushima nuclear power plant in 2011. Currently, work is actively underway to create generation IV reactors. The main objective of generation IV – in addition to ensuring safety – is the closure of nuclear fuel cycle.

The improvement of the safety system and the efficiency of the VVER technology occurs throughout the whole time of these reactors operation. Modern Russian-designed reactors are based on a combination of active and passive safety systems, the use of which minimizes the likelihood of an accident and eliminates the risks of damage in the event of a hurricane, floods, earthquakes and other extreme external impacts.

International cooperation plays an important part for the exchange of experience and improvement of the safety of nuclear technologies and related regulation. The IAEA governing documents establish the importance of peer review missions in the field of safety.

The main expert missions in the field of safety are: the Operational Safety Review Team (OSART) and the Technical SafetyReview (TSR) mission. Key countries operating nuclear power plants, including France, China and Russia, have been hosting OSART missions and follow-up visits most regularly since 1983.

The IAEA Member States regularly submit national reports on the implementation of obligations under Article 5 of the Convention on Nuclear Safety, 1994. The reports contain up-to-date information about the implementation of their safety obligations and is presented for "peer review" at meetings.

In addition to the IAEA, there are other fora for the exchange of best practices and assessment of NPP projects safety – the certification of the International Club of European Operating Organizations (European Utility Requirements, EUR) and the Multinational Design Evaluation Programme within the framework of the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD NEA).

A separate group of the CDA criteria is dedicated to the issues of water use and control of radioactive and non-radioactive emissions and discharges.

Due to the large volumes of water use in the technological process during the NPP operation, the issue of water consumption and wastewater management is strictly supervised. At the NPP construction and operation stages, both environmental monitoring of the terrestrial and aquatic ecosystems of the site location area (including groundwater) and quality control of discharged waters (concentration of pollutants and radioactive substances and temperature regime of the water area) is carried out.

Confirmation of the absence of adverse effects of NPP operation on human health or the environment is provided though the results of the analysis of systematic monitoring of the radiation situation in the areas where nuclear power plants are located, as well as measurements of the activity of radionuclides in air, water, soil, sediments, vegetation, animal organisms and food products. Strict control of non-radioactive emissions into the atmosphere is also necessary. Standards for emissions of pollutants are established by national legislation.

The CDA criteria regarding the safe operation of nuclear power plants are not fundamentally new. Most of them are reflected as references to the current EU directives, the IAEA and WENRA safety standards.

KEY CRITERIA OF THE CDA TO THE EU TAXONOMY IN THE FIELD OF SAFETY AT THE NPP OPERATION STAGE

1. The activity fulfils the requirements of Directive 2009/71/Euratom, implemented in accordance with the international guidance of the IAEA and WENRA relating to extreme natural hazards, including floods and extreme weather conditions.

2. Environmental degradation risks related to preserving water quality and avoiding water stress are identified and addressed, in accordance with a water use and protection management plan, developed in consultation with stakeholders concerned.

3. Radioactive discharges to air, water bodies and ground (soil) comply with individual licence conditions for the specific operations, where applicable, or national threshold values in line with Directive 2013/59/Euratom establishing basic safety standards for protection against threats arising from exposure to ionizing radiation and Directive 2013/51/Euratom establishing requirements for the protection of public health as regards the quantitative content of radioactive substances in water intended for human consumption.

4. Non-radioactive emissions are within or lower than the emission levels associated with the best available techniques (BAT-AEL) ranges set out in the best available techniques (BAT) conclusions for large combustion plants. For nuclear power plants greater than 1 MW thermal input but below the thresholds for the BAT conclusions for large combustion plants to apply, emissions are below the emission limit values set out in EU Directive 2015/2193 on limiting emissions of specific air pollutants from medium-sized combustion plants.

VVER TECHNOLOGIES (GENERATION III+)

Reactor type: pressured water reactor (PWR), classified as a Generation III+ reactor

Operating lifetime: 60 years with the possibility of extension

Capacity: 1200 MW (20% more than the previous generation reactor)

Unit capacity factor: up to 90%

Hardening of VVER-TOI shell - Energomashstal JSC

ADVANTAGES

- Meets the requirements of the IAEA standards, the EUR Club and the «post-Fukushima» requirements of WENRA
- Combines active and passive safety systems, including the flagship solution – the melt trap
- A number of additional safety measures for earthquake resistance and hypothetical severe accidents have been applied
- Can be used in different conditions without changing the basic conceptual, design or layout technological solutions
- Capability to operate for 18 months without refueling
- Can be operated using MOX fuel without any modifications
- The cost and duration of the construction, as well as operating costs are reduced as much as possible

Leningrad NPP-2

DESIGN FEATURES

- The reactor vessel is made of special 20 cm thick steels capable of withstanding high radiation loads
- The volume of the containment is about 75 thousand cubic meters, which minimizes the risk of accumulation of hydrogen inside in an explosive concentration
- The reactor core containment allows withstanding the fall of a large airliner, an 8-point earthquake, tornadoes or whirlwinds up to 56 m/s
- The containment withstands an internal pressure of 5 kg/cm2, i.e., if all the water supplied to the reactor turns into steam, the shell will withstand this enormous pressure
- The containment has 2 thick concrete shell walls: the outer one is 80 cm thick, the inner one is 1.2 meters thick, its structure featuring special steel cables. The total thickness of the double protective containment is about 2,5 meters

VVER SAFETY SYSTEM (GENERATION III+)

FOUR HIGH-PERFORMANCE BARRIERS:

The first barrier is a fuel pellet, which prevents the release of radiation through the cladding of the fuel element.

The second barrier is the fuel element cladding itself made of zirconium alloy, which prevents radiation from entering the coolant (water) of the primary reactor coolant circuit.

The third one is the primary reactor coolant circuit preventing release of fission products under the containment.

The fourth one is a system of containments that can withstand an airplane crash, a tornado, a hurricane or an explosion, enormous internal pressure and external impact of a shock wave.

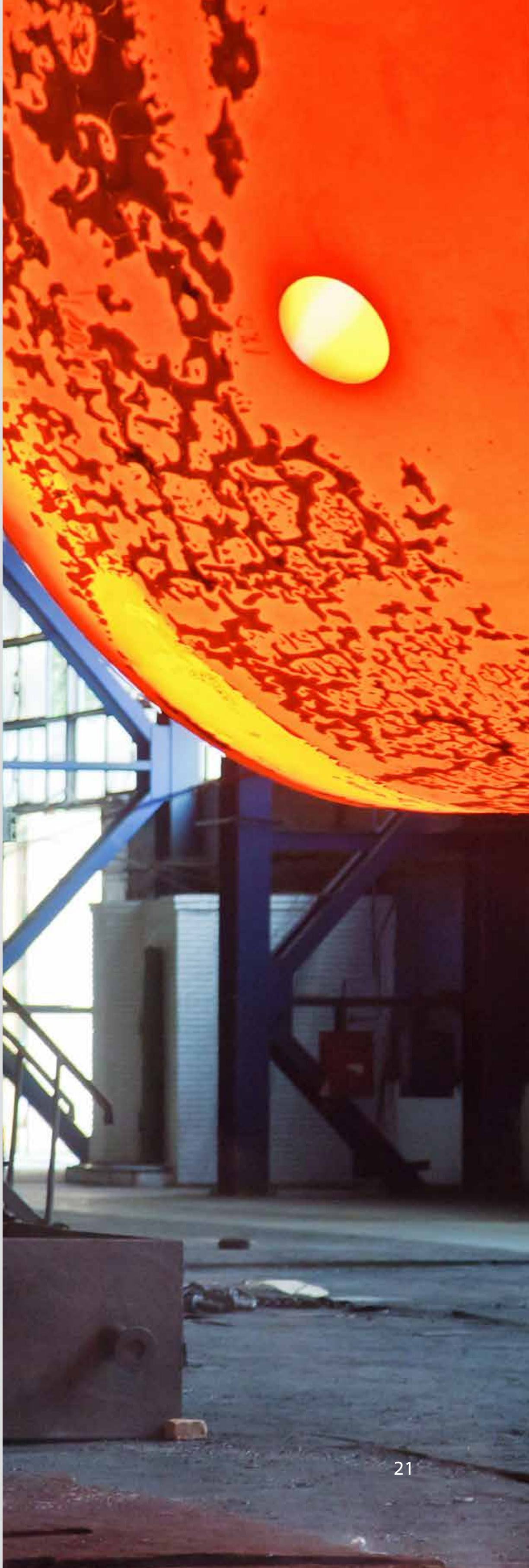
Installation of a Melt Trap at the Kursk Npp-2 Under Construction

MELT TRAP

One of the most important passive safety systems of a nuclear power plant is a melt trap. The trap was first installed at the Tianwan nuclear power plant built in China under a Russian design. Now such systems are installed at all nuclear power plants with VVER reactors.

The melt trap is a cold crucible; it is located under the nuclear reactor of the NPP and is filled with the so-called “sacrificial” material of iron oxides and boric acid, which enables to instantly shut down the nuclear reaction.

The system is referred to as passive because in the case of a hypothetical accident, the molten fuel, without the participation of the human factor, but only under the influence of the force of Earth’s gravity, falls into a refractory bucket and remains in it. The weight of the melt trap is 750 tons.



Before forging the shell blanks on a 15000 tf press.
Forging and pressing shop

COMPLIANCE WITH REQUIREMENTS REGARDING INCREASING THE RESILIENCE AND THE ABILITY OF NEW AND EXISTING NUCLEAR POWER PLANTS TO COPE WITH EXTREME NATURAL HAZARDS, INCLUDING FLOODS AND EXTREME WEATHER CONDITIONS

The main EU document in the field of nuclear safety fundamentals is Directive 2009/71/Euratom on framework requirements in the field of nuclear safety of nuclear installations, which establishes measures to achieve a high level of nuclear safety, as well as its regulation.

The preamble notes the importance of regulatory authority cooperation within the framework of WENRA and organization of the IAEA peer review missions.

The Directive 2009/71/Euratom identifies the following key areas for ensuring nuclear safety: national legislative, regulatory and organizational framework (national regulatory framework), independent competent regulatory authority, primary responsibility of license holders, training to maintain the necessary knowledge and skills, public awareness and reporting.

The legislation of the Russian Federation in the field of ensuring the safety of NPP and nuclear fuel cycle complies with international standards on nuclear and radiation safety.

The Russian Federation has adopted the General Provisions for Ensuring the Safety of Nuclear Power Plants No. NP-001-15 dated 17.12.2015 and the Requirements for the Content of the Report on the Safety Grounding of a Nuclear Power Plant Unit with a VVER Reactor No. NP-006-16 dated 13.02.2017, which determine the composition and content of documented and confirmed design solutions for all stages of the NPP life cycle, including operation and decommissioning.

The regulatory body issues licenses for the relevant scope of permitted actions on the basis of documents submitted by the operator. The effectiveness of such procedure has been repeatedly confirmed through inspections by the competent authority and the IAEA review missions.

Kursk NPP

Compliance of the Russian technologies and approaches with the IAEA standards, on which the Euratom directives are based, is also confirmed by the regular international peer review of the national reports of the Russian Federation submitted in accordance with Article 5 of the Convention on Nuclear Safety, 1994.[7]

Such partner review meeting is a unique forum at which experts of the Parties to the Convention on Nuclear Safety, once in every three years, have a solid opportunity to share information about achievements and problems in the field of nuclear safety of nuclear power plants.

Improving the resilience of new and existing nuclear power plants to natural disasters, including floods and extreme weather conditions, meets the principles of the Vienna Declaration on Nuclear Safety.[8]

According to these principles, when carrying out activities in the field of the use of nuclear energy, country should take into account the relevant IAEA safety standards and reflect this in its national reports under the Convention on Nuclear Safety 1994, starting from the seventh review meeting.

The 7th National Report of the Russian Federation in 2017[9] underwent a full cycle of peer review by all states that were parties to the Convention on Nuclear Safety 1994.

[7] The Convention on Nuclear Safety, 1994 (INFCIRC/449)

[8] Vienna Declaration on Nuclear Safety, 2015 (INFCIRC/872)

[9] The Seventh National Report of the Russian Federation on implementation of obligations arising from the Convention on Nuclear Safety, 2016 (7th National Report of the Russian Federation_Eng)

AKKUYU NPP

Country: Turkey

Reactor: VVER-1200

Capacity: 4 units x 1200 MW

Current stage: licenses have been obtained for the construction of power units No. 1 (April 2018), No. 2 (August 2019), No. 3 (November 2020) and No. 4 (October 2021)

Akkuyu NPP

AKKUYU NPP IS TOLERANT TO:

- **an external explosion with a pressure of 30 kPa;**
- **earthquake of 9 points;**
- **floods and tsunamis (located at an altitude of 10.5 m above sea level);**
- **the fall of an aircraft weighing 400 tons and moving at a speed of 200 m/s;**
- **wind speeds up to 56 m/s (observed 1 time in 1000 years).**

THE PROJECT OF TURKEY'S FIRST AKKUYU NUCLEAR POWER PLANT

The project of Turkey's first Akkuyu nuclear power plant in Mersin province was developed in accordance with the requirements of international and Turkish legislation in the field of atomic energy use.

According to the Turkish regulatory act «On Nuclear Power Plant Sites»[10] dated 21.03.2009 No. 27176, at the design stage of the Akkuyu NPP – as for an NPP site located on a riverbank or on seashore – potential negative external factors (both humans caused and natural ones), including geological, meteorological and hydrological events, were necessarily taken into account.

According to the requirements in effect, the National Report of the Republic of Turkey on the Stress Tests of the Akkuyu NPP has been prepared for consideration by the European Group of Nuclear Safety Regulators ENSREG.[11] According to the report, the Akkuyu NPP project implies a margin for a 1 m rise in the level of the world ocean due to global warming throughout the entire period of construction and operation.

The Akkuyu NPP project assumes the possibility of a combination of many different risk factors, including rising sea levels, wind wave formation, high tide, storm surge, barometric effects and seasonal fluctuations in water level. As a result of taking into account the potential overlapping of these factors, the construction site of the Akkuyu NPP is reliably protected even in the event of an increase in sea level by 8.63 m.

According to available calculations, the maximum wave height of a potential tsunami in the region of the NPP construction site can be up to 6.55 m with the probability of such a tsunami occurring once every 10,000 years.

In addition to the protection from rising sea levels caused by global warming, the Akkuyu NPP construction site is reliably protected from the effects of precipitation and storm runoff. The project provides for special drainage channels, underground storm sewers and storm grates. Drainage and water discharge facilities will ensure reliable drainage of storm water into the sea.

[10] Regulations of the Turkish Atomic Energy Agency "On Nuclear Power Plant Sites" No. 27176 dated March 21, 2009 (Turkish official gazette)

[11] Turkish Atomic Energy Authority, European "Stress Test" for NPP, National Report of Turkey (rev. 2), 2018 (National Report, Turkey)

The IAEA Technical Safety Review (TSR) mission is an independent expert evaluation that covers a wide range of activities carried out for the design, licensing and operation of nuclear installations. The project review address aspects of design safety and generic reactor safety, deterministic and probabilistic safety assessment methods, as well as risk-informed decision-making approaches.

From 1983 to 2022, Russia received seven TSR missions. In 2013 and 2014, TSRs on Generic Reactor Safety area were successfully held, under which the design documentation of NPP projects with VVER generation III+ reactors was assessed.

During the IAEA OSART mission reviewing operational safety issues, a group of international experts conducts an in-depth analysis of operational safety performance at nuclear power plants. Factors affecting safety management and the performance of personnel are considered. The main focus of OSART is identification of inconsistencies between the NPP's operating practices and the requirements of the IAEA safety standards.

Although the OSART reviews mainly focus technical aspects, the experts conducting the review also determine the state of the safety culture and the problems existing in the organization. From 1983 to 2022, Russia received 12 missions and 10 follow-up visits.

Compliance of safety approaches with international requirements is assessed by the EUR Club. Rosenergoatom (Rosatom entity) joined the EUR club in 1993, almost immediately after its foundation.

The first Russian project to receive a certificate of compliance with EUR requirements was the project of an NPP with a VVER reactor in 2006. In 2019, experts studied the design of an NPP with a generation III+ VVER reactor and issued a certificate of compliance with up-to-date approaches to the safety and efficiency of NPPs.

International experts noted that the project with VVER technology passed the most thorough and in-depth examination and fully meets the EUR requirements.

In addition to the IAEA, there are other foras for cooperation and exchange of experience in the field of peaceful use of nuclear technologies, for example, the OECD NEA. The Russian regulatory body (Rostechnadzor), along with the regulatory authorities of Canada, China, Finland, France, Japan, the Republic of Korea, South Africa, Great Britain, the USA, India, Sweden, Turkey, the UAE, Hungary and Argentina, as well as representatives of the IAEA, participated in the Multinational Design Evaluation Programme (MDEP)[12] Under the auspices of the OECD Nuclear Energy Agency.

In 2013, a Working Group chaired by Russia was established to evaluate the projects of new nuclear power plants with VVER (VVER WG)[13], which is attended by representatives of regulatory authorities of Turkey, Finland (suspended participation in May 2022), China, India (participated until the end of 2021) and Hungary.

The safety assessment of new Russian NPP projects with generation III+ VVER reactors was carried out within the framework of VVER WG.

The activities of VVER WG provide for the comparison and coordination of approaches and criteria for safety assessments, identification of differences in regulatory requirements applied in the participating countries, conducting joint safety assessments of Russian NPP projects with VVER reactors (those under construction or planned for construction in the VVER WG participating countries).

According to the joint assessments of certain aspects of the safety of Russian VVER technologies carried out by VVER WG, there were no obstacles to licensing NPP projects with VVER reactors in the VVER WG participating countries.

The importance of the assessment by the European Nuclear Safety Regulatory Group (ENSREG) is specifically noted in the CDA.

The best available technologies are understood in the CDA as technologies that fully comply with the provisions of Directive 2009/71/Euratom dated 25 January 2009 on framework requirements in the field of nuclear safety of nuclear installations, as well as the most relevant technical parameters of the IAEA standards and the goals/control levels of WENRA.

In terms of non-radioactive emissions, compliance with the EU Directive 2015/2193 dated 25 November 2015 on limiting emissions of specific air pollutants from medium-sized combustion plants is required to ensure compliance with the best available technologies. No specific technical parameters or lists of the best available technologies are provided in the CDA.

[12] NEA Multinational Design Evaluation Programme (MDEP) (oecd-nea.org)

[13] NEA Multinational Design Evaluation Programme (MDEP), VVERAWG (oecd-nea.org), a multinational program for evaluation of new NPP designs (gosnadzor.ru)

PAKS-2 NPP

Country: Hungary

Reactor: VVER-1200

Capacity: 2 units x 1200 MW

Current stage: a license is obtained for the construction of power units Nos. 5 and 6 (August, 2022)

Paks-2 Npp Mockup Model

CONSTRUCTION PAKS-2 NPP

On March 30, 2017, the Hungarian State Regulatory Authority issued a license for the use of the Paks-2 NPP construction site. As part of the procedure for issuing a license for the use of the construction site, a Preliminary Safety Analysis Report was prepared, issued on October 18, 2016.

The report includes an analysis of the risks associated with natural disasters and confirmation that reactor installations are able to withstand such risks.

The report also contains a comprehensive analysis of hydrological, geological and geophysical studies, confirming that the site is suitable for the construction of new power units that are resistant to all extreme natural phenomena.

Information on the Paks-2 NPP construction project is also provided on pages 39-40.

BELARUSIAN NPP

Country: Republic of Belarus

Reactor: VVER-1200

Capacity: 2 units x 1200 MW

Current stage: power unit No. 1 was put into commercial operation (June 2021); licenses were obtained for the beginning of physical start-up of power unit No. 2 (December 2021)

Belarusian NPP

THE CONSTRUCTION OF THE BELARUSIAN NPP

The construction of the Belarusian NPP was carried out in strict comliance with international standards, which is confirmed by the results of the IAEA missions that regularly take place in the Republic of Belarus.

Over the period 2012-2021, more than 10 missions recommended by the IAEA for countries building their first ever nuclear power units were carried out. International experts have confirmed the reliability and safety of the Belarusian NPP.

Despite the fact that the Republic of Belarus is not a member of the EU, in 2017 the country on its own initiative passed stress tests and partner verification of their results by the European Group of Nuclear Safety Regulators ENSREG.[14]

Experts of the European Commission, as well as representatives of independent regulators implemented stress tests. The stress test criteria included examination of the nuclear power plant reliability in case of natural disasters, in particular earthquakes and floods, as well as various man-made accidents.

The risks caused by the human factor were also checked – from errors of the NPP operator to terrorist attacks at the plant.

[14] National Report of the Republic of Belarus on the Belarusian NPP Objective Safety Reassessment (Stress Tests), 2017 (National Report, Belarus)

COMPLIANCE WITH THE REQUIREMENTS REGARDING THE IDENTIFICATION AND ELIMINATION OF RISKS OF WATER RESOURCES QUALITY DETERIORATION IN ACCORDANCE WITH WATER MANAGEMENT PLAN

Nuclear power plant construction projects shall, in the first instance, comply with the do no significant harm principle. When designing a nuclear power plant, an environmental impact assessment is carried out, including risk management program for water use.

Based on the experience of implementing projects in Russia, Rosatom conducts environmental monitoring of terrestrial and aquatic ecosystems condition, as well as monitoring the subsoil of the construction site area condition.

Each country has its own national legislation regulating the management of water resources. The water legislation of Russia consists of the Water Code dated 3 June 2006 No. 74-FZ and other legal acts. Regulatory framework for water resources considers water objects as an essential component of the environment, the habitat of flora and fauna, including aquatic biological resources, a natural resource used by humans for personal and household needs, economic and other activities.

Around each nuclear power plant in Russia, there is a sanitary protection zone, where certain restrictions are applied - for example, a ban on the residence of the population, a surveillance zone (may be different – for example, about 11 km), where radiation monitoring is applied for environmental objects according to dozens of indicators.

The relevant requirements are determined by specific norms and regulations approved by the Federal Medical and Biological Agency (FMBA) of Russia. According to these norms and regulations, the concentration of radioactive substances in the air, in cooling ponds (including fish and aquatic plants), in soil and vegetation, locally produced food, etc. is monitored in the surveillance zones. The results are presented in reports on the radiation situation in the NPP areas.

Besides, the territorial administrations of the FMBA of Russia also conduct selective radiation monitoring of environmental objects and products made in the territory of protective zones.

EU Directive No. 2000/60/EC dated 23 October 2000 on the fundamentals of water policy activities establishes the requirement for a river basin management plan and specifies that the issue belongs to an EU member state. In the Russian Federation, an organization operating a nuclear power plant is a participant in water relations based on water use agreement, in which the volumes of permissible intake (withdrawal) of water resources are established. The discharge of pollutants with sewage and (or) drainage waters is allowed on the basis of a decision on the provision of a water body for use and a permit for the discharge of pollutants into the environment (water bodies).

The operating organization conducts regular monitoring of the water condition (including temperature control) in order to obtain an interconnected and complete overview of the water condition.

The temperature regime of the water environment of the NPP cooling ponds coincides with the regime of water reservoirs; the temperature of the cooling ponds does not exceed the regulatory requirements established by the ”Rules for the operation of cooling ponds”.

In Russia, the principle of reimbursement of water supply costs is in effect. In accordance with the requirements of the regulatory body, Rostechnadzor, the operating organization is obliged to monitor all discharges of nuclear power plants into surface waters, monitor the intake of fresh surface and groundwater and the accumulation of fresh surface water.

The water to be used can be taken from surface or underground waters, provided that the use of this source does not hamper the achievement of environmental protection goals established for the source in question (licensing, rationing). To reduce water consumption from natural reservoirs in NPP projects with generation III+ VVER reactors, the use of circulation cooling system with evaporative cooling towers is provided.

CASE STUDY:

REDUCTION OF WATER CONSUMPTION UPON THE TRANSITION TO GENERATION III+ VVER TECHNOLOGIES

By the end of 2021, the Leningrad NPP had reduced production requirements for seawater by almost a third. The total volume of water resources of the Gulf of Finland used by nuclear power plants in technological processes amounted to 2.7 billion m^3, which is 29.26% lower than last year's figures.

Belarusian NPP. Spray pools consist of four 18,000 m3 ferroconcrete tanks. All the tanks are equipped with systems of pressure pipelines apportioning the chilled water among the spraying nozzles.

REDUCTION IN WATER CONSUMPTION

The significant reduction in water consumption is due to the fact that part of the electricity is produced by VVER generation III+ reactors having a circulation cooling system with evaporative cooling towers.

The design features of the new power units make it possible to significantly reduce the volume of water consumption of the nuclear power plant from natural reservoirs. The amount of seawater taken decreased by 1.1 billion m^3 compared to the previous year.

In general, the replacement of two units with RBMK reactors with power units with VVER reactors led to a decrease in water consumption by 45%, which reduces the station's water use costs.

The long-term biological and chemical monitoring of the Leningradskaya NPP cooling pond, which is carried out on an ongoing basis together with the St. Petersburg Scientific Center of the Russian Academy of Sciences, shows that, over the period of the operation of the NPP, the nuclear facility has produced no noticeable impact on the state of the air or water environment.

The Leningradskaya NPP keeps constant records of water consumption and wastewater disposal volumes, as well as the Gulf of Finland water quality control.

Direct discharges of pollutants into groundwater are prohibited. As part of the implementation of eco-analytical control over the sources of anthropogenic impact of nuclear power plants, work is being carried out on biotesting the waters of cooling ponds of nuclear power plants, as well as work on the examination of cooling ponds for the presence of pathogens of infectious diseases of bacterial, viral, and parasitic nature.

Within the framework of industrial environmental control, the state of terrestrial and aquatic ecosystems of the NPP location area is monitored. In the course of the work, an assessment of the state of ecosystems by biotic and abiotic components is carried out, as well as radiation monitoring in the areas of the NPP location.

In addition, the biological and chemical monitoring of circulating and technical water supply systems of nuclear power plants is implemented. The operating organization is developing long-term programs to prevent biological fouling on the equipment of the NPP service water supply systems.

At the NPP, cooler reservoirs are monitored on an ongoing basis, which are used to cool heated circulating water in circulating water supply systems. In order to ensure the proper functioning of cooling reservoirs, water samples are regularly taken and analyzed, and their biological reclamation is exercised. It is about the release of herbivorous fish species into reservoirs, which help to fight blue-green algae to improve water quality and curb the growth of phytoplankton.

The process of fish stocking takes place with the participation of specialists from the departments of environmental protection of nuclear power plants, departments of state control of the Federal Agency for Fisheries, FSBI Glavrybvod, as well as research institutes.

NPP construction projects must be implemented in accordance with the requirements of national legislation regulating the use of water resources, including for projects on the territory of the EU – in accordance with the requirements of EU legislation, which includes both ensuring compliance of the concentrations of pollutants with the established standards of permissible discharge, and ensuring the temperature regime of the water area in the area of discharge of cooling waters, including in the cold season.

CASE STUDY:

REPLENISHMENT OF ICHTHYOFAUNA OF NPP RESERVOIRS

Participants: Rosenergoatom Concern and its NPP branches
Geography: Russia
Stakeholders: local communities, regional authorities

Fish stocking of cooling ponds of Russian NPPs

In 2021, Rosatom organizations carried out work on the artificial reproduction of aquatic biological resources:

- **Beloyarskaya NPP** - the Beloyarsk water reservoir was stocked with bighead carp, grass carp and black carp (428 thousand fry);
- **Kalininskaya NPP** - the Udomlya water reservoir was stocked with black carp (82.7 thousand fry);
- **Smolenskaya NPP** - fish stocking of the cooling pond with white carp, grass and black carp (91.3 thousand fry) was carried out;
- **Rostovskaya NPP** - fish stocking of the cooling pond with silver carp, black carp and European carp (3 tons of fry);
- **Kurskaya NPP** - fish stocking of the cooling pond with silver carp (4.5 tons of fry) was carried out.

THE FISH STOCKING OF NPP

Significant volumes of water resources are used in the VVER technological process. Water is used as a moderator of the atomic reaction and a coolant in the reactor, for the transfer of thermal energy from the reactor to the turbine, as well as for the removal of residual heat in turbine condensers. For these purposes, water is used from the cooling ponds (reservoirs), where special intake and spillway structures are installed.

The fish stocking of NPP cooling ponds is a common practice for nuclear power plants in Russia.

First of all, it is of technological nature: fish stocking is necessary for biological reclamation and maintenance of natural processes of self-purification of reservoirs. In warm water, there is an intensive growth of algae and the reproduction of mollusks, and this, in turn, affects the operation of water intake pumps, reducing the effective operation of the station’s service water supply systems.

Herbivorous fish are able to largely neutralize this negative effect. In addition, as a result of fish stocking, the amount of phytoplankton decreases, the water quality and the ecological condition of the reservoir as a whole improve.

Replenishment of the ichthyofauna of reservoirs is carried out at the expense of the nuclear power plants themselves. Such fish species as silver carp, European carp, salmon, wild carp, grass carp, black carp, etc. are released into cooling ponds.

Fish help to maintain a favorable balance of aquatic organisms, preserve ecological well-being and diversity of species inhabiting the pond.

In the reservoirs at the NPP, studies of the state of fish stock are regularly conducted. The volume of annual fish stocking is calculated by specialists of regional branches of the FSBI Glavrybvod. The release of fish into reservoirs is carried out under the strict supervision of specialists of nuclear power plants, representatives of the state control, supervision and protection of aquatic biological resources, veterinary services and other organizations responsible for the environmental well-being of the region where the NPP is located.

During the release of juveniles into the reservoir, not only the declared volume and species compliance are checked, but also the veterinary report on the condition of the fish. During the fish stocking and for another 15 days, fishing is prohibited in reservoirs within a radius of 500 meters from the place where the juveniles were released. Anti-poaching raids are carried out to protect aquatic biological resources.

The water in the cooling ponds is clean, and Rosatom holds fishing competitions, including international ones, on their territory. For example, in 2019, fishermen from Hungary, Egypt, India, Bangladesh and Turkey – countries with which Rosatom cooperates - came to the competitions near the Leningrad NPP. Thus, Rosatom shows to residents of the countries where it builds stations that the energy they are about to receive is environment-friendly.

Another positive effect of fish stocking is the possibility of selling farmed fish. For example, a fish nursery with four lines for breeding commercial fish - carp, trout, sturgeon, silver carp, sterlet - has been created on the facilities of the spillway canal of the cooling pond of the Beloyarskaya NPP.

In 2020, the output was increased to 60 tons. The buyers are wholesalers and residents of a nearby town, where the NPP has opened its own fish shop this year. The store sells both fresh fish and semi-finished fish products, hot smoked products. In Udomlya, four fish farms specialize in breeding sturgeon fish, trout. The farms produce more than 300 tons of fish products per year, as well as about 6 million fry of various fish species.

PAKS-2 NPP

Country: Hungary

Reactor: VVER-1200

Capacity: 2 units x 1200 MW

Current stage: a license is obtained for the construction of power units Nos. 5 and 6 (August, 2022)

Paks-2 NPP mockup model

A WATER MANAGEMENT PLAN

As part of obtaining a license for the construction of Paks-2 NPP, a Preliminary Safety Analysis Report was prepared for new NPP power units with VVER-1200 reactors.

The report contains a water management plan, according to which the source for cooling the condensers of NPP turbines is running water from the Danube River. The document strictly regulates both the water intake and the mode of water discharge into the Danube after cooling the condensers, including the exact temperature regime, which allows to keep water use within the normal limits, which is strictly controlled by the Hungarian regulatory authority.

For other water use items, including the provision of water to nuclear power plants for technical and utility needs, the norms of proper Hungarian legislation shall apply, which comply with the requirements of EU regulations.

Information on the Paks-2 NPP construction project is also provided on pages 28-29.

COMPLIANCE WITH THE REQUIREMENTS REGARDING RADIOACTIVE RELEASES AND DISCHARGES

Radioactive emissions into the air, water bodies and soil pollution by them comply with the conditions of validity of licenses for specific works (operations), where applicable, or national thresholds in accordance with Directive 2013/59/Euratom and Directive 2013/51/Euratom.

The radiation impact of releases and discharges of radioactive substances on the population and the environment is limited by national legislation, subject to international safety standards. In Russia, the regulatory body, Rostechnadzor, sets standards for maximum permissible emissions of radioactive substances into the atmosphere and standards for permissible discharges of radioactive substances into water bodies for each particular NPP.

Emissions and discharges of radioactive substances are allowed within the specified standards on the basis of Rostechnadzor permits. At all nuclear power plants, regular monitoring of compliance with emission standards is observed for all standardized radionuclides.

Radiation monitoring of environmental objects includes:

- monitoring of the gamma radiation dose rate and the annual dose on the ground (carried out in a continuous mode in the territories of the NPP sanitary protection zone and surveillance zone);
- control of contamination of air in the atmosphere, soil, vegetation, water in surface water basins;
- control of contamination of foodstuff and feeding stuff of local production.

The main factors of the radiation impact of nuclear power plants on the population and the environment include emissions of radioactive substances from nuclear power plants into the atmospheric air and discharges of man-made radionuclides into water bodies.

Continuous monitoring of compliance with the standards is carried out by the radiation safety departments of nuclear power plants. At the NPP, the state of radiation protection of NPP personnel, the population and the intake of radioactive substances into the environment is constantly monitored.

The results of the analysis of systematic monitoring of the radiation situation in the areas where nuclear power plants are located and measurements of the activity of radionuclides in air, water, soil, sediments, vegetation, animal organisms and food products confirm the absence of adverse effects of NPP operation on human health or the environment.[15]

[15] The Ninth National Report of the Russian Federation on implementation of obligations arising from the Convention on Nuclear Safety, 2022.

THE UNIFIED STATE AUTOMATED SYSTEM FOR MONITORING THE RADIATION SITUATION

The Unified State Automated System for Monitoring the Radiation Situation (EGASMRO)[16] is designed to provide informational support to activities of public authorities and management at all levels to ensure radiation safety on the territory of the Russian Federation.

The purpose of the state monitoring of the radiation situation is the timely detection of changes in the radiation situation, assessment, forecasting and prevention of possible negative consequences of radiation exposure for the population and the environment.

When designing a nuclear power plant, a special section of the design documentation «Radioactive Waste» is devoted to taking into account the requirements in the field of radioactive emissions and discharges, ensuring compliance of design solutions with both legislative requirements and issued permits, licenses and other documents for each specific NPP project.

The IAEA Safety Standards series contains the document GSG-9 «Regulatory Control of Radioactive Releases into the Environment»[17] of 2018, which defines the procedure for monitoring and controlling radioactive releases into the environment.

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[16] http://egasmro.ru/

[17] IAEA Safety Standards No. GSG-9 “Regulatory Control of Radioactive Discharges to the Environment”, 2018 (IAEA GSG-9)

RADIATION SAFETY OF PERSONNEL AND THE PUBLIC

In Russia, the principles of radiation safety, general requirements for the organization and conduct of dosimetric control of personnel exposure, requirements and standards for exposure to ionizing radiation are formulated in the Radiation Safety Standards (NRB-99/2009) and the Basic Sanitary Rules for Radiation Safety (OSPORB-99/2010).

Leningrad NPP

MINIMIZE THE RISKS

During normal operation, the limits of radiation doses during the year are set based on the following values of individual lifetime risk: for personnel – $1x10^{-3}$, for the population – $5x10^{-5}$, which corresponds to the recommendations of the IAEA.

With protection from potential exposure during a year substantiated, the following values are taken as the boundary values of the generalized risk (the product of the probability of an event leading to exposure by the probability of death associated with exposure): for personnel – $2x10^{-4}$ $year^{-1}$, for the population – $1x10^{-5}$ $year^{-1}$.[18]

The main dose limits equal to 50 mSv per year and 100 mSv for any consecutive five years have not been exceeded at any nuclear power plant. Individual radiation doses of 90% of NPP personnel do not exceed 5 mSv per year.

Emissions and discharges of nuclear power plants create insignificant doses of radiation to the population in the areas of nuclear power plants; radiation risks to the population due to planned emissions of radionuclides outside the NPP in normal operation are acceptable and create a dose of less than 10 mSv per year (risk less than 10^{-6} $year^{-1}$).

Generation III+ VVER technologies have made it possible to minimize the risks of a beyond-design-basis design accident, as a result of which it is possible to exceed the established limits of radiation exposure to the population and the environment.

[18] The Ninth National Report of the Russian Federation on implementation of obligations arising from the Convention on Nuclear Safety, 2022.

COMPLIANCE WITH NON-RADIOACTIVE EMISSIONS REQUIREMENTS

Non-radioactive emissions are within or below the emission levels associated with the technological performance of the best available technologies. IAEA Safety Standards No. GSG-9 “Regulatory Control of Radioactive Discharges to the Environment”, 2018.

For nuclear power plants with a thermal capacity exceeding 1 MW, emissions are set below the limit values set out in the EU Directive 2015/2193 dated 25 November 2015 on limiting emissions of specific air pollutants from medium-sized combustion plants.

The standards of maximum permissible emissions of pollutants into the atmospheric air are established by the state. The legislation of the Russian Federation on the protection of atmospheric air includes Federal Law No. 96-FZ dated 4 May 1999 «On the Protection of Atmospheric Air», Federal Law No. 7-FZ dated 10 January 2002 «On Environmental Protection» and related national by-laws.

On the basis of national regulations, standards for maximum permissible emissions of non-radioactive pollutants into the atmospheric air have been developed and approved at each NPP. Standards are established for each stationary source of emissions and NPP as a whole, for each pollutant and groups of substances.

The established normal rate must comply with the condition under which emissions from each source and the NPP as a whole will not create a surface concentration exceeding the maximum permissible concentration at the boundary of the sanitary protection zone.

The normal rates are established on the basis of summary calculations of the permissible negative impact on atmospheric air and are characterized by the following values: maximum one-time value, g/s; gross value, t/g. Emission control is carried out by instrumental and computational methods.

Incineration plants include any technical installation in which various types of fuel are oxidized in order to use the heat generated at the same time, for example, diesel generators - are used for the needs of nuclear power plants in emergency cases (for example, in case of incidents related to the lack of electricity supply) and are operated for a limited period of time (up to 500 hours operation per year; inspection is carried out once a month and after scheduled preventive maintenance).

At all nuclear power plants in Russia, accounting of emissions of pollutants into the atmospheric air and their sources is organized, industrial environmental control is carried out over compliance with established standards of emissions into the atmospheric air.

Work is being carried out at the NPP to check the efficiency and technical condition of the gas cleaning equipment, each gas cleaning plant has a certificate and all the necessary technical documentation.

The volumes of non-radioactive emissions of pollutants into the atmospheric air of nuclear power plants do not exceed the maximum permissible values and are significantly lower than the standards established by environmental authorities. There are no emergency or bulk emissions of pollutants into the atmospheric air.

In many Western European countries, a «permissive» system is used in the implementation of projects, implying the possibility of establishing individual, more stringent requirements for a particular project, including in the field of environmental protection.

REGULATION CASE STUDY: NON-RADIOACTIVE EMISSIONS AND BAT

The legislation of the European Union and Hungary contains standards for emissions and waste disposal. According to the license documentation of the Paks-2 NPP, non-radioactive emissions are within or below the emission levels associated with the technological indicators of the best available technologies (BAT).

Non-hazardous and hazardous non-radioactive waste of Paks NPP amounts to 1,434 and 276 tons per year, subject to the BAT. Similar waste from the Paks-2 NPP will amount to 800 and 100 tons per year, respectively. Therefore, non-hazardous non-radioactive waste is generated at the new Hungarian NPP in amounts 45% less, and hazardous non-radioactive waste in amounts 74% less than at the Paks NPP.

FUEL SOLUTIONS FOR NPPS AND THE PURSUIT OF NFC CLOSURE

KEY CONCLUSIONS

It should be noted that changing the existing fuel certification procedures will require additional time, which also calls into question the feasibility ofthe CDA requirements in terms of the 2025 deadline. Besides, the standardization of solutions that can be identified as accidenttolerant is a separate issue.

The CDA criteria in terms of nuclear fuel include the requirement to fully apply ATF from 2025, with its mandatory certification and approval by the national safety regulatory authority. At the same time, as of today, there are no universally accepted definition of ATF or its specific technical parameters.

The term accident tolerant fuel has become firmly entrenched in the nuclear energy agenda after the accident at the Fukushima Daiichi NPP (Japan) in March 2011. As a result of the reactor core heating, the temperature of the cladding of zirconium alloy fuel elements rose significantly. Zirconium cladding rapidly reacted with water steam at high temperature and was accompanied by release of hydrogen gas, what resulted in a steam explosion. Since then, the term accident tolerant fuel has been used to refer to nuclear fuel resistant to accidents. Such fuel must remain operational not only under normal conditions, but also in the conditions of loss-of-coolant accidents.

Three main approaches to the ATF development across the globe are: advanced coating of fuel pellets, advanced coating of fuel cladding and replacement of uranium dioxide fuel with silicide and/or nitride one. Experts agree that full-scale technological or even regulatory readiness for the use of accident tolerant fuel is not achievable by 2025 in any of these areas.

In addition, it remains uncertain how to prove the compliance with the use of ATF from 2025 requirement – obtaining a license for lead test/ partial/ full loading, partial/ full actual loading of ATF or completing the full qualification of the new fuel in accordance with the requirements of each national regulatory authority.

There is no clear procedure for identification of fuel as accident-tolerant. Same as any changes in the parameters of nuclear fuel, such identification should be carried out through the certification (licensing) procedure in accordance with the requirements of the national legislation of the country where the fuel will be used.

The criterion of certification of accident-tolerant fuel and approval by the national regulatory authority of the country using the technology requires the existence (development) of technological expertise from the regulatory authority, which also involves detailed and unambiguous interpretation of accident tolerance requirements. Such details may be introduced both at the EU level and directly by national regulatory authorities, subject to the availability of appropriate competencies.

It should be noted that changing/ comnpementing the existing fuel certification procedures will require additional time, which also calls into question the feasibility of the CDA requirements in terms of the 2025 deadline. Besides, the standardization of solutions that can be identified as accident-tolerant is a separate issue.

Additional criteria specified in the CDA, which is directly related to the nuclear fuel cycle, is the transition to a closed-cycle economy, meaning the mandatory (organizational, financial, technological) accounting in terms of the management of spent nuclear fuel, including spent ATF. Hence, the issue of spent nuclear fuel management should be considered when developing ATF technologies, as well as reflected in the national requirements for ATF and its licensing procedure.

Together with this group of CDA criteria, it is necessary to consider generation IV reactors aiming at closure of the nuclear fuel cycle (specifically fast neutron reactors). As the current edition of the CDA characterizes nuclear power as a transitional activity with a project implementation period of new NPP construction and existing NPP life extension until 2045 and 2040 respectively, it is reasonable to assume the possibility of development of other complementary delegated act with green criteria along with the advancing and commercialization of generation IV reactor technologies for the deployment of large-scale construction of such NPPs after 2045.

Rosatom places attention to the development of technologies for the complete closure of the nuclear fuel cycle, including the development of all necessary elements of infrastructure. In this area of work, Rosatom is implementing the “Proryv” project and offers the concept of „Balanced nuclear fuel cycle“, which currently combines products and solutions aimed at closing the fuel cycle of light-water reactors.

The goals of Balanced nuclear fuel cycle are achieved by introducing fast neutron reactors in the nuclear fuel cycle, thereby creating a so-called dual-component nuclear energy system, which includes not only traditional reactors on thermal neutrons, but also new generation IV reactors.

Balanced nuclear fuel cycle is a combination of four main components: spent nuclear fuel reprocessing with high-level waste fractioning; long-term storage systems for spent nuclear fuel and high-level waste; fuel from reprocessed nuclear materials (uranium plutonium fuel and regenerated uranium fuel); of minor actinide transmutation in fast reactors. The transition to dual-component nuclear energy system will increase the efficiency of uranium raw materials use and minimize the generation of radioactive waste.

KEY CRITERIA OF THE CDA OF THE EU TAXONOMY IN TERMS OF THE NUCLEAR FUEL CYCLE

The criteria for the nuclear fuel cycle provides in terms of the transition to Accident Tolerant Fuel from 2025, as well as striving to close the nuclear fuel cycle, including the aim of minimal radioactive waste generation.

In terms of nuclear fuel solutions, the criteria established in the CDA provide for the use of accident-tolerant fuel from 2025.

The requirements for the date of the beginning of its use can be revised taking into account "the technical progress in accident-tolerant fuel commercialisation in the EU and world-wide" (amendments made by the CDA to the Delegated Regulation of the EU 2021/2139 – para. 2, Article 2a).

In accordance with the CDA, accident-tolerant fuel shall be certified and approved by the national regulatory authority of the relevant country, i.e. pass the licensing procedure in a member state of the European Union.

In addition to the key criteria, the CDA also specifies additional criteria. An additional requirement directly related to the nuclear fuel cycle is the transition to the circular economy.

ACCIDENT-TOLERANT FUEL, HANDLING SPENT NUCLEAR FUEL

As of now, no specific requirements for accident tolerant fuel are formulated within the framework of the CDA. At the same time, despite the absence of any specific parameters of accident-tolerant fuel in the CDA at the moment, it is expected that European regulators will focus on the vectors of technological development of fuel, confirmed by European scientific developments.

Work on accident-resistant fuel types took place in the world long before the accident at the Fukushima NPP, yet such work received significant development after the events of March 2011.

The most extensive work on the development of accident-tolerant fuels is performed by the United States under the program of the US Department of Energy (DOE), which started in 2012 and involves significant amounts of funding. The program is expected to be completed by 2025.

The program involves Westinghouse (USA), Framatome (France) and GNF (a joint venture between GE and Hitachi). In 2019, all three companies loaded the first prototype assemblies with accident-tolerant fuel rods (Lead Test Rods) into US reactors.

Control of geometric dimensions of fuel assemblies (Machine-building plant)

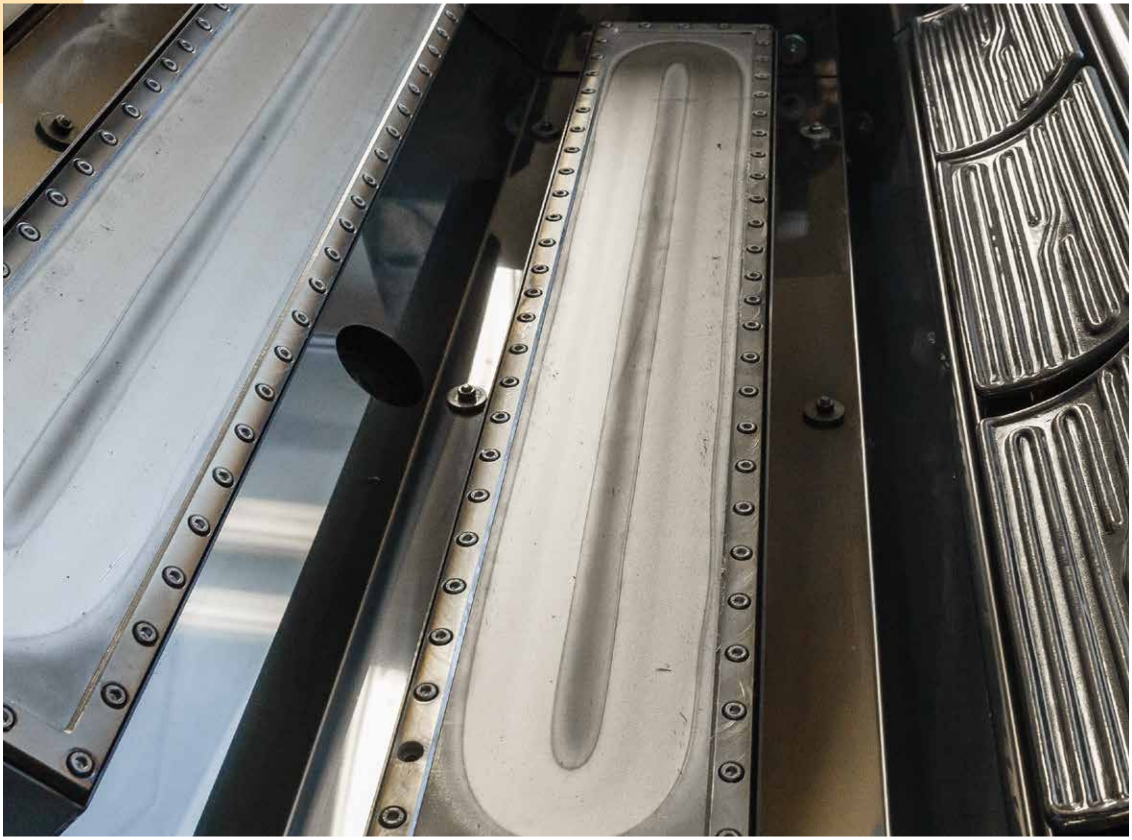
The main areas of development are the coating of Zr cladding of fuel elements (zirconium cladding, silicon carbide cladding) and the alloying of fuel pellets with chromium oxide Cr2O3.

Technological solutions for fuel modification already developed by Rosatom make it possible to avoid accidents associated with steam-zirconium reactions.

A high level of protection is provided, in particular, by means of an increased grain size in the fuel structure, as well as by means of active and passive safety systems of VVER generation III+ reactors. In 2018, experimental fuel assemblies of VVER and PWR produced by PJSC NCCP were loaded into the MIR research reactor of JSC SSC RIAR.

Two full test cycles have been completed. In 2021, Russia's first program for the irradiation of experimental fuel rods (LTR) began at power unit No.2 of Rostovskaya NPP.

Within the framework of this program, three assemblies of the TVS-2M type are irradiated, each of which contains 12 "accident-tolerant" fuel elements: six of them are made using a 42KhNM (In Russian: 42XHM) chromium-nickel alloy as a structural material and 6 are made with zirconium alloy cladding with a chrome coating.



Research and development of sputtered coating for accident-tolerant fuel, Bochvarov VNIIINM.
A sputtering magnetron module with a cathode target made of a material used to modify the surface of fuel element tubes.

The presence of an additional coating of the fuel element cladding opens up the question of reprocessing fuel with new characteristics, which is not explicitly considered in the CDA.

In the logic of association of the fuel solution and the management of spent nuclear fuel, the concept of "Balanced NFC" (BNFC) is implemented, as proposed by Rosatom. Besides, an additional criterion of the CDA – "transition to the circular economy" – provides for the maximum possible reuse of non-radioactive and radioactive waste.

With the successful introduction of fast neutron reactor technologies with a large integrated capacity and a considerable share in the country's nuclear power industry, minor actinides – the longest-lived fractions of radioactive waste that pose the greatest hazard if buried – can be disposed of within the framework of a two-component energy model.

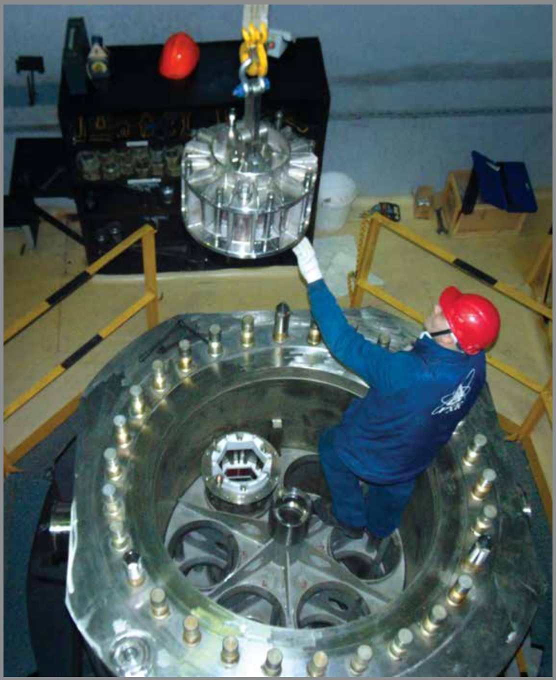
As a result of transmutation and multiple recycling, minor actinides turn into short-lived or stable elements, which significantly reduces the level of potential biological and radio ecological hazard posed by buried radioactive waste. This solution will be discussed in more details below (Decommissioning of nuclear power plants, radioactive waste management).

BALANCED NFC

The BNFC concept assumes multiple recycle of regenerated nuclear materials of nuclear power plants based on light-water reactors, along with drastic reduction (by hundreds of times) of the duration of radiological hazard of remaining radioactive waste from millennia to about three hundred years.

The fuel from reprocessed nuclear materials (uranium plutonium fuel and regenerated uranium fuel) proposed within the BNFC proposes loading up to 100% of the core of thermal reactors with such nuclear fuel with an estimated possibility of six to seven recycles, the number of which is limited only by the lifetime of the NPP unit.

The return of regenerated uranium and plutonium to the fuel cycle allows NPP operators to use their own resources more efficiently and to save natural uranium.



New transport packaging kit for the transportation of REMIX-fuel, FSUE GHK

THE BNFC CONCEPT IS A SET OF FOUR MAIN COMPONENTS:

1. spent nuclear fuel processing with high level radioactive waste fractionation;
2. systems for long-term storage of spent nuclear fuel and high level radioactive waste;
3. fuel from reprocessed nuclear materials (uranium plutonium fuel and regenerated uranium fuel);

4 afterburning of minor actinides in fast neutron reactors.

THE INTEGRATED IMPLEMENTATION OF ALL FOUR COMPONENTS ALLOWS (FOR AN EXAMPLE OF A TWO-UNIT NPP WITH A CAPACITY OF 2.4 GW (E) WITH AN OPERATIONAL LIFE OF 60 YEARS):

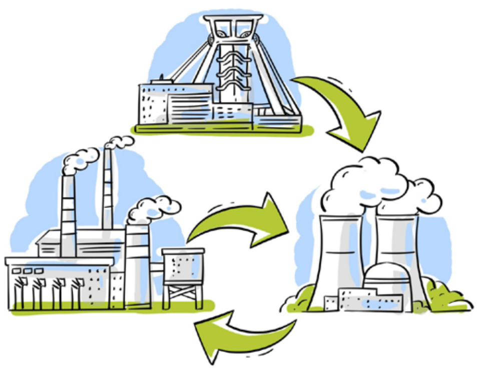
- to save up to 31% of natural uranium or its equivalents by recycling nuclear materials extracted from SNF;
- to reduce by more than 22% the costs of NPP operators for long-term temporary storage and disposal of spent nuclear fuel, typical for the strategy of direct disposal of spent nuclear fuel, expressed through contributions to the funds for financing deferred obligations for the management of spent nuclear fuel;
- to reduce by more than 6 times the amount of packaged radioactive waste in a boron-silicate glass matrix sent for disposal in customer countries in relation to the volume of spent nuclear fuel placed in SNF capsules in the case of its direct burial;
- to reduce from tens of thousands to about three hundred years the duration of burdening descendants with radiological hazard from radioactive waste to be buried.

Therefore, the BNFC is a practical example of a closed-loop economy. At the moment, this is the only example of this kind in the world.

SNF dismantling and storage. Leningrad NPP

A NEW TECHNOLOGICAL PLATFORM FOR NUCLEAR ENERGY BASED ON FAST NEUTRON REACTORS AND CLOSED NUCLEAR FUEL CYCLE TECHNOLOGIES

As soon as in the first half of the 21st century, it is planned to form a two-component nuclear power system with thermal and fast neutron reactors, along with the parallel development of the relevant closed NFC infrastructure.



The most effective closure of the NFC, that is, the involvement of nuclear materials regenerated from SNF in the NFC, is implemented in fast neutron reactors.

An increase in the share of such reactors in the energy balance will ensure sustainable energy supply for millennia to come by gradually reducing the dependence of the industry on uranium raw materials, eliminating the accumulation of spent fuel from thermal reactors and minimizing the formation of RAW, which fully complies with the key principles of the closed-cycle economy.

Apart from Russia, China is engaged in the creation of two-component nuclear power industry. China adheres to a three-stage strategy for the development of fast reactors: experimental reactor, pilot reactor and commercial reactor. At the moment, two CFR-600 experimental reactors are being built in China, scheduled to be put in operation in 2023. The start of construction of the first commercial reactor – CFR-1000 – is scheduled for 2028 with the commercial operation to begin in 2034.

Today, two fast neutron reactors – BN-600 and BN-800 – are operating at the Beloyarskay NPP (Russia). Due to their specifics, such reactors do not only produce electricity, but also accumulate (refine) plutonium for its reuse in VVER thermal reactors.

BELOYARSK NPP

Location: near the town of Zarechny (Sverdlovsk region)

Number of power units: 4 (in operation – 2)

Reactor type: AMB (units No. 1 and 2), BN-600 (unit No. 3), BN-800 (unit No. 4)

Overall installed capacity: 1485 MW.

Beloyarsk NPP

Power unit BN-800 of Beloyarsk NPP

FAST BREEDER REACTORS

Currently, two power units are in operation at the Beloyarskay NPP – BN-600 (commissioned in 1980) and BN-800 (commissioned in 2015). These are the world's largest power units with fast breeder reactors. In terms of reliability and safety, the fast neutron reactor is among the best nuclear reactors in the world.

The possibility of further expansion of the Beloyarskaya NPP with introducing power unit No. 5 with a 1200 MW fast reactor – the main commercial power unit for serial construction – is being considered.

PRORYV PROJECT

The Proryv project is aimed at achieving a new quality of nuclear energy, the development, creation and industrial implementation of a closed nuclear fuel cycle (CNFC) based on fast neutron reactors developing large-scale nuclear power.

The ceremony of pouring the first concrete of the BREST-OD-300 reactor of the Proryv Project

BASIC REQUIREMENTS:

1. To prevent accidents at nuclear power plants requiring evacuation, or even resettlement of the population;

2. To ensure the competitive ability of the nuclear power industry in comparison with alternative generation, primarily with combined-cycle plants, but also with solar and wind power plants, taking into account the total costs of fuel cycles (based on a comparative analysis of LCOE);

3. To form CNFC for the full use of the energy potential of natural uranium raw materials;

4. To approach consistently the radiation-equivalent (in relation to natural raw materials) disposal of radioactive waste;

5. To strengthen technologically the non-proliferation regime (consistent abandonment of uranium enrichment for the nuclear power industry, development of weapons-grade plutonium in the blanket and separation during the processing of SNF, reduction of transportation of nuclear materials).

MAIN ADVANTAGES:

The radiation-equivalent approach in the CNFC is the principal way to solve potential environmental problems when dealing with radioactive waste. It actually means that radiation safety of the environment is guaranteed not by the use of any hardware and techniques but by absence of any activity exceeding the existing natural levels.

To date, the possibility of deep extraction of actinides (>99.9%) from all types of radioactive waste has already been experimentally demonstrated, which substantiates the technical feasibility of a radiation-equivalent approach to the disposal of radioactive waste.

Within the scenario of development of the nuclear power industry in Russia in the 21st century with thermal and fast neutron reactors, it has been established that:

• equalization of expected radiation doses from radioactive waste materials and from natural raw materials (radiation equivalence) is achieved 287 years after the generation of nuclear energy waste in 2100;

• equalization of lifetime radiation-related risks of possible induction of cancer from radioactive waste and from natural raw materials (radiological equivalence) is achieved 99 years after the generation of nuclear energy waste in 2100.

The pouring the first concrete of the BREST-OD-300 reactor of the Proryv Project

CASE STUDY:

DEMONSTRATION OF TECHNOLOGIES OF A FAST NEUTRON REACTOR WITH LEAD COOLANT AND CLOSED-LOOP NFC ENTERPRISES

The pilot demonstration energy complex (PDEC), being built within the Proryv Project area in the town of Seversk, Tomsk region, is designed to demonstrate the possibility of using nuclear power plants as a full-fledged renewable energy source based on "natural" safety technologies and closed NFC.

The complex consists of a fast neutron reactor (FNR) with a lead coolant BREST-OD-300 with an electric capacity of 300 MW(e) and on-site fuel cycle enterprises for the fabrication and processing of nuclear fuel.

The use in BREST-OD-300 of an integrated reactor layout with a high-boiling, radiation-resistant, weakly activated lead coolant, inert in contact with water and air and not requiring high pressure, makes it possible to exclude accidents leading to evacuation of the population, and this significantly increases the attractiveness of the technology for future consumers and the social acceptability of nuclear power in general.

The use of dense nitride fuel in the FNR will create conditions for achieving full reproduction of fissile nuclides in the core and stabilizing the breeding properties of the reactor, which is also important from the point of view of compliance with the non-proliferation regime and reproduction of valuable energy resources.

The use of uranium-plutonium fuel to start the reactor at the initial stage of operation will demonstrate the possibility of efficient recycling of plutonium from SNF of thermal reactors, in which further operation will require feeding with waste uranium, which has been accumulated in large amounts in the world.

Replication of these solutions will completely eliminate the problem of accumulation of minor actinides and SNF and the limitations of the resource base of natural uranium.

At the same time, the potential biological hazard (PBH) of waste obtained after the reprocessing of spent nuclear fuel will be equal to the PBH of the source uranium raw materials as soon as within hundreds of years (the PBH of spent nuclear fuel and the source uranium raw materials in the open cycle would reach the same values in ~700,000 years).

ADVANTAGES OF USING TECHNOLOGIES IMPLEMENTED IN THE PDEC:

- «natural» safety of energy technologies;
- no visible restrictions on the resource base;
- minimization of environmental impact (no danger to the biosphere);
- guaranteed reduction of the PBH of finally isolated waste to the level of the source uranium raw materials within a time frame acceptable to the general public;
- technological support of the nuclear waste non-proliferation regime.

IMPLEMENTATION OF THE PROJECT

The territory of the Siberian Chemical Plant accommodates the PDEC, with a unique power unit with a BREST-OD-300 reactor with lead coolant at its heart. In addition to the reactor, the PDEC includes a fabrication/refabrication module (FRM) for the manufacture of mixed uranium-plutonium fuel and a nuclear fuel cycle-closing reprocessing module (RM) for irradiated MNUP fuel. The on-site fuel cycle has a common system for handling RAW.

R&D results have been obtained to substantiate the main equipment, core products, structural materials, and lead coolant technology, which made it possible to proceed with the creation of the BREST-OD-300 reactor plant. All components of the unique equipment have been experimentally tested on small- and medium-scale models (some of the models for testing PDEC technologies were developed from scratch).

In February 2021, a license was obtained from Rostechnadzor (the regulatory body of Russia) for the construction of a pilot power unit with this innovative reactor plant. On June 8, 2021, the first concrete was poured into the foundation slab of the power unit at the SCP site in Seversk; in November 2021, the concreting of the foundation plate was fully completed.

Currently, the installation of FRM equipment is successfully continuing. In 2022, it is planned to conduct regular tests of fuel assemblies as part of the development and substantiation of fuel elements with MNUP fuel for reactors with lead and sodium coolants. It is planned to update the simulation models of the FA production line in terms of modeling the delivery and installation of equipment using lifting mechanisms. It is planned to put the FRM into pilot operation in the first half of 2024.

The third mandatory element of PDEC is the module for reprocessing irradiated nuclear fuel. It is planned to gradually implement a combined technology for processing MNUP SNF, including head, pyrochemical and hydrometallurgical processing. In 2021, research work on pyrochemical technology has reached the stage of design, manufacture and testing of pilot equipment.

The tasks for 2022 include the production of models of innovative equipment for the PDEC RM, holding a number of tests, including a gas purification system for a pilot high-level waste (HLW) conditioning unit, continuing the creation of a hardware and methodological complex for the RM, as well as the development and approval of the concept for launching the reprocessing module.

Currently, the transition is underway from the development to the construction and commissioning of the main commercial power unit with a 1200 MW sodium-coolant fast neutron reactor as part of the Beloyarskaya NPP.

A project is being developed for a commercial power unit with a fast neutron reactor with a lead coolant in combination with fuel cycle production facilities as part of an industrial energy complex (IEC). Pilot commercial demonstration of technologies based on lead coolant reactors and closed NFC is expected to take place by the 2030s.

All this opens up opportunities for the widespread introduction of fast neutron reactors into the nuclear industry and the formation of a two-component structure of nuclear power, with giving it a new quality. All these works performed in Russia as part of the Proryv Project.

An important milestone in the transition to a closed nuclear fuel cycle in the peaceful use of nuclear energy is the mass construction of generation IV reactors. One of the options for the closure of the nuclear fuel cycle is the construction of fast neutron reactors in combination with on-site modules for the fabrication/refabrication of fuel and the reprocessing of spent nuclear fuel.

Such a solution would expand the resource base of nuclear power, minimize logistical risks during the transportation of radioactive materials, and allow solving the problem of spent nuclear fuel accumulation today without passing it to the following generations

DECOMMISSIONING OF NUCLEAR POWER PLANTS, RADIOACTIVE WASTE MANAGEMENT

KEY CONCLUSIONS

The EU Taxonomy CDA contains criteria regarding the safe management of radioactive waste and decommissioning of nuclear power plants, since responsible provision of the final stage of the life cycle is a necessary condition for safety and non-harm to the environment, human life and health.

Most of the CDA criteria in the final stage of the life cycle relate to the legislation/ infrastructure of the country where the NPP is located. The CDA lacks definitions, specific values or technical parameters; the criteria in place mostly contain references to the requirements of the current EU directives and IAEA safety standards.

In some countries, spent nuclear fuel is considered a valuable resource, which implies its reprocessing, while in others, spent nuclear fuel is qualified as radioactive waste due to the lack of reprocessing technologies. The difference in approaches significantly affects the interpretation of the CDA criteria.

Radioactive waste management has two vectors – minimal formation of radioactive waste and safe management of radioactive waste. There are no clear requirements regarding the treatment of radioactive waste, either, in the CDA; such requirements may be further clarified in EU regulations or reflected in national legislation.

Decommissioning, as well as the radioactive waste management requires the establishment of an integrated system. First, it is necessary to develop a regulatory framework that sets the basic principles and specific limits, parameters. Secondly, technological infrastructure is required, such as facilities for physical and radiological characterization, site decontamination, dismantling, materials management, and disposal of radioactive waste, as well as specialized equipment.

Thirdly, financial support for decommissioning and radioactive waste management should be provided. Fourthly, regulatory bodies should be created or granted appropriate authority, which will be responsible for issuing licenses (other official permits) and monitoring (inspection, sanctions).

Rosatom is developing technologies for the closure of NFC, which makes it possible to minimize the formation of radioactive waste through the treatment and further use of SNF. Moreover, already accumulated radioactive wastes are subject to treatment in Russia.

A separate area of work is to reduce the risk of radioactive waste. Process of extraction and after-burning of minor actinides i.e., the transition of the longest–lived fraction of radioactive wastes into short-lived or stable elements can significantly improve the efficiency of disposal.

This contributes to a significant reduction in the period of potential danger and avoiding the need to construct deep burial sites by placing short-lived radioactive waste fractions in near-surface and mid-depth burial sites.

This approach allows to manage the risks associated with the absence of favorable geological conditions, as well as to reduce the total costs of management of radioactive waste from spent nuclear fuel.

KEY CRITERIA OF THE CDA OF THE EU TAXONOMY IN TERMS OF THE FINAL STAGE OF THE LIFE CYCLE

There are four groups of criteria that the CDA imposes on new projects in terms of the NFC and NPP life cycle (LF) back end:

1. Availability of the fund (financial and operational resources) for the management of RAW and decommissioning by the date of approval of the project. Confirmation of the availability of the necessary resources at the end of the life cycle of the facility for the radioactive waste management and decommissioning;

2. The availability of an operating facility for the final isolation of all very low-level (VLLW), low-level (LLW) and intermediate level wastes (ILW). Availability of a detailed plan for the commissioning of a storage facility for high-level waste (HLW) by 2050;

3. The use of the best available technologies in the project, providing for minimal generation of radioactive waste. Availability of such technologies in the pre-commercial stage;

4. Spent nuclear fuel and radioactive waste are handled in a safe and responsible manner.

Complex for processing and disposal of solid radioactive waste (SRW) at Leningrad NPP.

ASSESSMENT OF COMPLIANCE WITH THE CDA CRITERIA OF THE EU TAXONOMY IN TERMS OF THE BACK END OF THE LIFE CYCLE

First of all, it should be noted the non-specificity of the definitions of spent nuclear fuel and radioactive waste. Since some of the EU member states consider SNF to be a resource and intend to reprocess it, while other member states have no such opportunity and store the SNF, EU documents allow the attribution of SNF to both recyclable products and RAW.

Rosatom's approach implies an unambiguous attribution of SNF to resources (which corresponds to the requirement of CDA on the transition to a closed-cycle economy), and therefore all issues related to the management of SNF are discussed in Chapter "Fuel technologies and closing the nuclear fuel cycle".

The IAEA, whose standards are referred to by the CDA criteria, recommends classifying radioactive waste depending on the duration of their hazard and relative activity. It is recommended to have appropriate disposal facilities for all this waste in the country.

In this chapter, RAW is understood only as materials that do not provide for further use and are subject to conditioning (bringing the RAW to the physical form and condition suitable for their burial and meeting the acceptance criteria) and burial. These are, in particular, NPP operational RAW; RAW formed during the decommissioning of nuclear power plants; and RAW arising during the treatment of spent nuclear fuel.

In terms of detailing the requirements for the RAW management and decommissioning of NRHF (nuclear and radiation hazardous facilities) the DDA contains references to the following EU directives:

Directive 2011/70/Euratom of 19.07.2011 on framework requirements in the field of responsible and safe management of SNF and RAW.

Directive 2011/70/Euratom defines the following main areas for ensuring responsible and safe management of SNF and RAW: national regulatory framework, independent competent regulatory body, primary responsibility of license holders, training to maintain the necessary knowledge and skills, financial resources, informing employees and the public, national programs, notification and reporting.

The document contains references to other EU directives that are somehow applicable to SNF and RAW (on physical security, cross-border movements, mandatory monitoring, transparency of control, etc.).

In addition, Directive 2011/70/Euratom contains definitions of the basic concepts related to the management of SNF and RAW, the basic principles of the organization of the management of SNF and RAW, as well as requirements for the presence of bodies responsible for the management of SNF and RAW in the member countries and financial institutions that ensure this activity.

One of the key requirements is the requirement for regular reporting on the status of national systems for the management of SNF and RAW to the European Commission. The CDA criteria for RAW generally duplicate the key requirements of Directive 2011/70.

One of the most balanced national RAW management infrastructures is the one in operation in France. The illustration shows a facility for the disposal of LLW and VLLW in Manche (Manche disposal facility). It is already closed (sealed) and is under monitoring. (https://cli-manche.fr/csm-andra/presentation-de-la-cli/)

Directive 2013/59/Euratom of 05.12.2013 establishes basic safety standards for protection against threats arising from exposure to ionizing radiation.

Directive 2013/59/Euratom contains a list of decisions of the European Council and its directives related to radiation protection.

The document regulates the basic approaches to measuring the level of radioactive radiation and protection against it, contains definitions of the main terms and characteristics, including formulas for their calculations, provides general principles for the organization of radiation protection, describes tools for improving radiation protection and recommendations for the organization of training and informing the population, fixes the requirements mandatory for the EU member states, in particular, in terms of responsibility allocation, licensing, reporting, etc. In addition, Directive 2013/59/Euratom establishes rules for the supervision of national practices by the EU.

In general, the criteria for the final stage of the life cycle relate not so much to nuclear power projects (such as, for example, a new NPP or new fuel for nuclear power plants), as to the national infrastructure for SNF and RAW management and decommissioning of nuclear and radiation hazardous facilities.

FINANCIAL AND OTHER NECESSARY RESOURCES TO ENSURE DECOMMISSIONING AND MANAGEMENT OF RADIOACTIVE WASTE

Pilot demonstration engineering center for decommissioning. Plasma reprocessing complex (PRC). Operators are taking water consumption readings at the RAW PRC.

The criterion concerning the financial provision of decommissioning and management of RAW, up to their burial, includes:

1. availability by the date of approval of the project of the fund (financial and operational resources) for the management of RAW and decommissioning;

2. confirmation of the availability of the necessary resources at the end of the LC facility for the management of RAW and decommissioning.

This criterion applies to the state that has decided to develop nuclear energy. A supplier of a nuclear facility, nuclear fuel or related services can only take into account the contributions to the relevant fund in the price structure of its products.

In modern practice, when launching a nuclear power plant construction project in a country that had no previous experience in operating nuclear power plants, in preparation for the project implementation, a contractor organization can provide services for the formation of a national nuclear infrastructure, including recommendations on the organization of funds for the management of SNF and RAW, as well as for decommissioning of NRHF, with description of the principles of filling of these funds, the structure of funds and drafts of relevant legislative acts. This approach is being implemented, including by Rosatom.

The IAEA also provides assistance in the creation and development of the necessary nuclear infrastructure to countries initiating the development of nuclear energy. Such assistance is provided through advisory service missions, training courses, publication of guidance documents and reference materials.

The criterion establishing the requirements for the disposal of radioactive waste includes:

1. the availability of an operating facility for the final isolation of all VLLW, LLW, ILW;

2. the availability of a detailed plan for the commissioning of a storage facility for HLW and long-lived intermediate RAW by 2050 (for projects extending the life of nuclear power plants, the requirement applies from 2025);

3. RAW is disposed in its country of origin, unless there is any agreement between this country and another country to which the RAW is shipped. This criterion also applies to the state implementing a project in the field of nuclear energy development.

As a solution that meets this criterion, it is possible to bring into compliance the Rosatom project for the development of a standard «Radioactive waste final disposal facility» (RAWDF), which ensures the safe disposal of radioactive waste of classes 3 and 4 generated as a result of the operation of the NPP: both operational RAW and RAW from the reprocessing of SNF and RAW from decommissioning of NRHF.

Radioactive waste final disposal facilities are formed based on standard solutions for the design and equipment, taking into account the results of scientific research and tests to study the properties of the short-lived fraction of HLW from SNF treatment.

The RAW life cycle comprises four main stages (All these must be adequately funded):

1. Conditioning (Including Reprocessing)

2. Temporary Storage

3. Transportation

4. Final Burial

A container for the disposal of RAW is a key link for any infrastructure for the management of RAW – in accordance with the characteristics of this container, RAW conditioning facilities, RAW temporary storage facilities, final disposal facilities are designed, vehicles are selected, etc.

MINIMAL GENERATION OF RADIOACTIVE WASTE AND USE OF THE BEST AVAILABLE TECHNOLOGIES

The criterion establishing the minimum formation of RAW when using the BAT implies that the new technologies introduced in the NFC will provide for the minimum generation of RAW.

At the same time, the CDA does not provide specific parameters of minimality. In particular, it is not specified which RAW parameter should be minimum.

The operating organization establishes standards for the generation of RAW and is periodically reviewed subject to the positive record achieved in the management of RAW.

The total activity of RAW produced at nuclear power plants is an almost unchangeable value, and a decrease, for example, in the volume of RAW, will lead to an increase in their specific activity.

Only the extraction and reuse of so-called useful elements, such as uranium and plutonium, can significantly reduce the amount of radioactive waste sent to burial.

EXAMPLE OF A TECHNOLOGY FOR THE RAW DISPOSAL

The BNFC concept involves the reprocessing of SNF with the release of a short-lived fraction (137Cs and 90Sr) of RAW.

This will significantly reduce the period of potential danger of radioactive waste and avoid the need to construct deep burial sites by placing short-lived fractions of radioactive waste in near-surface and mid-depth burial sites.

This approach will reduce the risks associated with the lack of favorable geological conditions, as well as the total costs of management of RAW from SNF.

The large-scale introduction of fast neutron reactors within the nuclear industry with the ability and technologies for transmutation (afterburning) of minor actinides (Am and Np-237) will also significantly reduce the amount of radioactive waste to be placed in radioactive waste disposal sites.

TRANSMUTATION (AFTERBURNING) OF MINOR ACTINIDES IN FAST NEUTRON REACTORS

Minor actinides – americium (Am), neptunium (Np), curium (Cm) are fission products arising from radiation neutron capture by isotopes of uranium and plutonium. Their total content in VVER SNF is less than 1% (by weight), but their radiation hazard is a significant problem in the final isolation of RAW.

Currently, various methods of transmutation (afterburning) of minor actinides are proposed, for example, the use of specialized burn-out reactors (e.g., liquid salt reactors), as well as their disposal in fast neutron reactors.

The large-scale introduction of fast neutron reactors will allow the transmutation (afterburning) of minor actinides on an industrial scale.

MAIN ADVANTAGES:

- A VVER reactor produces about 20 kg of Am per year (after 10 years of exposure after unloading from the reactor);
- A BN-1200 reactor can potentially dispose of 20 kg or more of Am, on average, in 1 year;
- the radiotoxicity of radioactive waste, determined by minor actinides, is reduced by about 100 times during the fractionation of HLW and after transmutation (afterburning) of minor actinides.

Among the criteria of the CDA there is a requirement for the best available technologies – at the time of approval of financing, they must be at least at the pre-commercial stage. The illustration shows a Pluto installation, which uses plasma-pyrolytic technology for the reprocessing of radioactive waste, as well as the final product of this installation – vitrified slag in receiving containers. This technology has been implemented in Russia at a number of experimental sites, but has not yet been widely used. Nevertheless, it meets the CDA criteria for applicability in new nuclear projects.

Installation "Pluto"

SAFE AND RESPONSIBLE HANDLING OF RADIOACTIVE WASTE

The criterion establishing the need to handle SNF and RAW in a safe and responsible manner[19] primarily applies to a state developing nuclear projects, referring to the requirements of directives adopted by Euratom in previous years.

The EU directives contain requirements for sending SNF and RAW for treatment to another country – the infrastructure necessary for management of SNF and RAW must be confirmed in the recipient country, and its safety must comply with international legislation.

To date, such infrastructure exists in Russia (a group of companies in the structure of Rosatom and the Federal State Unitary Enterprise "National Operator for Radioactive Waste Management") and France (the Orano group of companies and the French National Agency for the Management of Radioactive Waste (ANDRA)).

States submit national reports to the IAEA Secretariat as part of the implementation of the provisions of the Joint IAEA Convention on the Management of Radioactive Waste and Spent Nuclear Fuel.

The Russian Federation regularly submits their national reports as part of their obligations to SNF and RAW management[20].

Confirmation of the readiness of the Russian infrastructure to work safely with foreign SNF is the successful experience gained over the past 15 years in treatment of spent nuclear fuel from nuclear power plants and research reactors from 17 countries of the world. Such infrastructure currently exists only in France, and is operated by ANDRA.

[19] Directive 2011/70/Euratom and Directive/2013/59/ Euratom

[20] The Fifth National Report of the Russian Federation on implementation of obligations arising from the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 2017 (5th National Report of the Russian Federation_Eng)

CASE STUDY:

RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL MANAGEMENT IN GERMANY

After the German federal government decided to shut down nuclear programme, the so-called Act on Allocation of Responsibilities for Nuclear Waste was adopted in 2016, according to which the power companies operating nuclear power plants were obliged to transfer ~ 24 billion euros to the national fund, after which responsibility for the management of SNF and RAW would pass to the federal government.

It was expected that these funds, which include a 35% risk premium, would be enough to ensure the safe disposal of 10,200 tons of spent nuclear fuel and more than 1 million m3 of RAW, which would be accumulated in Germany by the time of shutdown and decommissioning of all nuclear power plants.

A complex system of responsibility distribution between several ministries for various actions to ensure the safe storage and disposal of SNF and RAW has been organized and currently exists.

A number of state-owned specialized enterprises responsible for various aspects have been established: safe management of SNF and RAW (German Federal Office for the Safety of Nuclear Waste Management), temporary storage of SNF and RAW (German Federal Society for Temporary Storage), final disposal of SNF and RAW (German Federal Company for the Disposal of Radioactive Waste) and others.

A national plan for the search for sites and the construction of repositories for RAW and SNF has been adopted. At the same time, there are serious concerns that these actions will not solve the problem, because the safety of SNF burial has not been proven, the site for the burial ground has not been selected (and the candidate municipalities, one by one, refuse to host it), the creation of technological means is delayed, and all this can lead to a rapid exhaustion of the financial fund for handling of SNF and RAW. Meanwhile, all SNF and most of the RAW materials are still stored at the NPP sites.

CASE STUDY:

FINANCING OF RAW CONDITIONING AND DISPOSAL ACTIVITIES IN RUSSIA

As an example of the organization of the national RAW management system, we can cite the scheme of filling and spending of the RAW management fund implemented in the Russian Federation:

• owner and supervisor of the special reserve fund for the radioactive waste management is a specialized organization authorized by Federal Law – the Rosatom State Atomic Energy Corporation;

• the fund is filled with contributions from the companies engaged in activities that result in the formation of radioactive waste; these companies are required to have financial support for the limit of liability, including the availability of documentary evidence of such financial support;

• definition and classification of radioactive waste are set forth at the level of federal laws and regulations supporting them; depending on the level of activity, isotopic composition, and other properties in the Russian Federation there are 6 groups (classes) of RAW;

• the national regulatory body (Federal Tariff Service) periodically publishes tariffs for the disposal of each of the groups of RAW; tariffs are set in the format of "rubles per cubic meter";

• companies, as a result of whose activities RAW is formed, shall calculate and transfer to the fund the money required to ensure the disposal of RAW according to tariffs, in accordance with the volumes of RAW produced by them;

• thus, companies, as a result of whose activities RAW is formed, become interested in ensuring that the amount and level of activity of the RAW produced by them is minimal;

• the decision of the government defines the enterprise – the national operator for the management of radioactive waste which will be the only organization authorized to conduct activities for the final isolation of radioactive waste, as well as to perform other related functions; in the Russian Federation, such an enterprise is FSUE "NO RAO" as specified;

• the national operator is responsible for the construction, operation and closure of RAW final isolation facilities, the development of infrastructure for the RAW management, ensuring the safety of accepted RAW management, informing the public about the management of RAW, etc.; this activity is funded from the special reserve fund for the RAW management.

An example of responsible management of SNF and RAW in the framework of new projects can be a radioactive waste disposal facility – Rosatom product designed for countries that are at the very beginning of development of national nuclear energy. All waste generated by NPPs can eventually be brought to a condition acceptable for disposal in a near-surface and/or medium-depth facility. The illustration shows an arrangement for handling each of the types of RAW within the described concept.

In Russia, the national RAW management infrastructure consists of several components. First of all, this is legislation[21] that establishes the basic principles („the polluter pays", „RAW materials must be buried", etc.), allocates responsibilities and normalizes levels, limits and tariffs.

The second component is the technological infrastructure – stations[22] for reception, conditioning and disposal of radioactive waste, as well as the corresponding auxiliary equipment – transport, instrumentation, container production, decontamination equipment, etc.

The third component is financial institutions that ensure the filling, maintenance and efficient spending of enterprises' contributions for the RAW management. And, finally, the fourth component is the regulatory authorities that issue licenses and certificates provided for by law, audit enterprises and monitor the state of the system as a whole.

All four components are closely related to each other, and the effectiveness of the functioning of the national system as a whole directly depends on the effectiveness of each component.

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[21] The main laws regulating the SNF and RAW management in the Russian Federation include:

- Federal law No. 7-FZ "On environmental protection" dated January 10, 2002 (as amended of March 26, 2022).
- Federal Law No.190-FZ dated 11.07.2011 "On the RAW Management and Introduction of Changes into Some Legal Acts of the Russian Federation" (as amended of December 21, 2021).
- Federal Law No. 170-FZ dated 21.11.1995, (as amended on April 30, 2021) "On the Use of Atomic Energy"
- Federal Law No.317-FZ dated 01.12.2007 (as amended on July 02, 2021) "On Rosatom State Nuclear Energy Corporation".
- Decree of Rostechnadzor dated 05.08.2014 No. 347 (as amended on November 12, 2018) "On approval of the federal norms and rules in the sphere of the use of nuclear energy "Safety during radioactive wastes management. General provisions" (together with NP-058-14).

[22] Detailed information about the reception, conditioning and disposal of RAW in the Russian Federation, the branch network of the national operator for RAW, the technologies used, licenses, etc. can be found on the website of FSUE "NO RAO": https://www.norao.ru/about/

The Russian national nuclear infrastructure includes, in particular, the RAW treatment facilities located at the NPP sites, the branch network of RAW storage and treatment of the Federal Environmental Operator, the final RAW isolation facilities constructed by the National Operator for RAW, as well as a set of federal laws and industry regulations and rules governing the interaction between infrastructure facilities and subjects.

All these elements are included in Rosatom's technologies for the formation of infrastructure for the radioactive waste management, which can be useful to countries beginning to develop nuclear power engineering.

The entire life cycle of nuclear power plants (including the construction stage) for modern projects is 80 years; the practice of extending the service life may lead to the postponement of the organization of temporary (off NPP site) storage and disposal of radioactive waste, decommissioning of nuclear power plants.

The issue of construction and commissioning of a nuclear power plant always takes priority in the allocation of finance and technology.

Rosatom's nuclear power plant construction technologies provide for the possibility of solutions that allow conditioning and safe storage of operational radioactive waste for 10 years – during this time, the country in which the NPP is being built expects to create the necessary national infrastructure for the radioactive waste management, or at least part of such infrastructure, ensuring the safety of radioactive waste in the medium-length time period.

Such an approach is possible, but it is not typical, as it leads to significant overexpenditure for the creation of temporary solutions, such as the equipment of temporary storage facilities for RAW, monitoring their safety, recertification of containers and, possibly, their repackaging, etc.

CASE STUDY:

REHABILITATION OF TERRITORIES AND REDUCTION OF RAW VOLUMES IN BELGIUM

Geography
- Dessel, Antwerp province (Belgium)

Interested parties
- Residents of Dessel (Belgium)
- Local authorities of the province of Antwerp (Belgium)
- Framatome (France)

Sorting potentially contaminated soil

PROJECT PROFILE

FBFC International (Franco-Belge de Fabrication du Combustible, French-Belgian fuel production, is a subsidiary of Framatome) is a plant for the production of fuel assemblies in Dessel (Belgium). In October 2013, FBFC International obtained a license to decommission the enterprise.

In order to remove the territory of a nuclear and radiation hazardous facility from radiation supervision after its decommissioning, it was necessary to clean it and provide documentary evidence that the site was not contaminated with radionuclides (the relevant indicators should be below the emission limits). An important stage in the restoration of such sites is the characterization and sorting of potentially contaminated bulk materials.

The rehabilitation of the territory as part of the decommissioning of the FBFC International plant for the production of nuclear fuel was carried out using the FREMES system developed by NUKEM Technologies (part of the TVEL Fuel Company).

The system is designed for the separation of radiation-contaminated bulk materials by streaming gamma-spectrometric measurements on a conveyor with subsequent automatic sorting according to specified limit values based on a radionuclide vector.

ADVANTAGES OF USING FREMES TECHNOLOGY:

- tenfold reduction in the volume of contaminated soil;
- significant shortening of time frames for the implementation of land restoration projects;
- applicability for the most common radionuclides polluting the soil, their detection at low levels of activity (gamma emitters 137Cs, 60Co, etc.).

Belt conveyor free release measurement system

IMPLEMENTATION

The implementation of the project in Dessel began in 2017 from the design and purchase of equipment.

Over two and a half years, the FREMES system treated about 45 thousand tons of potentially contaminated materials, of which about 10 thousand tons were crushed building structures and 35 thousand tons of soil.

The level of radionuclide removal was 95% (lower than 1 Bq/g), about 90% of the sorted soil was cleaned and approved for use.

Due to the use of the facility, the volume of radioactive waste at the plant has decreased tenfold. The FREMES system has provided a multiple increase in the productivity of sorting, characterization and certification of bulk radioactive waste by the radionuclide vector, the productivity of which is 10-100 tons/hour.

ABBREVIATIONS AND ACRONYMS

ENSREG	European Nuclear Safety Regulatory Group
EUR	European Utility Requirements – Club of European Operating Organiza-tions
WENRA	Western European Nuclear Regulators Association
NPP	Nuclear Power Plant
OECD NEA	The Nuclear Energy Agency of the Organization for Economic Cooperation and Development
OECD NEA	The Nuclear Energy Agency of the Organization for Economic Cooperation and Development
VVER	Water Cooled, Water Moderated Power Reactor
NRHF	Decommissioning Of Nuclear- And Radiation-Hazardous Facilities
CDA	Complimentary Delegated Act of the European Commission 2022/1214 of Mar 09, 2022 defining additional criteria for nuclear and gas generation projects
EGASMRO	Unified State Automated System for Monitoring the Radiation Situation
EU	European Union
LC	Life Cycle
CNFC	Closed Nuclear Fuel Cycle
HLW	High Level Radioactive Waste
IAEA	International Atomic Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LLW	Low-Level Radioactive Waste
BAT	Best Available Technologies
BAT	Best Available Technologies
VLLW	Very Low Level Waste
OSART	the IAEA Technical Safety Review (TSR) mission
SNF	Spent nuclear fuel
RAWDF	Radioactive Waste Disposal Facility
RAW	Radioactive Waste
RBMK	High Power Channel Type Reactor

VVER WG	Working Group for evaluation of projects of new nuclear power plants with VVER at the OECD NEA site
Rostechnadzor	Federal Environmental, Industrial and Nuclear Supervision Service
MLW	Medium Level Radioactive Waste
BNFC	Balanced Nuclear Fuel Cycle
EU Taxonomy	Regulation of the European Parliament and of the Council of the European Union 2020/852 of June 22, 2020 on the establishment of a framework for the promotion of sustainable investment and making amendments to EU Regulation 2019/2088
TCP	the IAEA Technical Safety Review (TSR) mission
FMBA	Federal Medical Biological Agency of Russia
NFC	Nuclear Fuel Cycle

APPENDIX. EU REGULATIONS

Treaty establishing the European Atomic Energy Community (Euratom Treaty) of 1957
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012A/TXT&from=EN
• Article 2(b) provides for the establishment of uniform safety standards to protect the health of workers and of the general public; • Article 30 provides for the establishment of basic standards for the protection of the health of workers and the general public against the dangers arising from ionising radiations; • Article 37 requires Member States to provide the Commission with general data relating to any plan for the disposal of radioactive waste; • Article 41 requires Member States to...; • Annex II establish project areas for the notification to the Commission of investments in nuclear energy.
Council Regulation 2587/1999(9)/Euratom of 2 December 1999 defines the investment projects to be communicated to the Commission according to Article 41 of the Euratom Treaty
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999R2587&from=EN
The regulation establishes thresholds and other requirements for notification of investments in nuclear energy to the European Commission.
Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0071&from=EN
The Directive establishes measures to achieve a high level of nuclear safety, as well as its regulation. The preamble noted the importance of the interaction of regulatory bodies in WENRA and the invitation of IAEA missions. The Directive identifies the following key areas for ensuring nuclear safety: national legislative, regulatory and organizational framework (national regulatory framework), independent competent regulatory authority, primary responsibility of license holders, training to maintain the necessary knowledge and skills, public awareness and reporting.

Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent nuclear fuel and radioactive waste

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32011L0070&qid=1659354968311&from=EN

The Directive defines the following main areas for ensuring the responsible and safe management of SNF and RAW: national regulatory framework, independent competent regulatory body, primary responsibility of license holders, training to maintain the necessary knowledge and skills, financial resources, informing employees and the public, national programs, notification and reporting.
The document contains references to other EU directives that are somehow applicable to SNF and RAW (on physical security, cross-border movements, mandatory monitoring, transparency of control, etc.). In addition, Directive 2011/70/Euratom contains definitions of the basic concepts related to the management of SNF and RAW, the basic principles of the organization of the management of SNF and RAW, as well as requirements for the presence of bodies responsible for the management of SNF and RAW in the member countries and financial institutions that ensure this activity. One of the key requirements is the requirement for regular reporting on the status of national systems for the management of SNF and RAW to the European Commission. Curiously, the CDA criteria for RAW generally duplicate the requirements of Directive 2011/70, but not all, but only those in respect of which there have been difficulties or delays in the EU member states in recent years.

Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32013L0059&qid=1659356225657&from=EN

Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation. Directive 2013/59/Euratom contains a list of decisions of the European Council and its directives related to radiation protection. The document regulates the main approaches to measuring the level of radioactive radiation and protection against it, contains definitions of the main terms and characteristics, including formulas for their calculations, provides general principles for the organization of radiation protection, describes tools for improving radiation protection and recommendations for the organization of training and informing the population, sets forth the requirements which are mandatory for the EU member states, in including in terms of responsibility allocation, licensing, reporting, etc. In addition, Directive 2013/59/Euratom establishes rules for the supervision of national practices by the EU.

Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32011L0092&qid=1659358497310&from=EN

Assessment of the environmental impact of those projects that may have a significant impact on the environment and assessment of compliance with the requirements established for the issuance of permits. The Directive contains requirements for conducting an environmental impact assessment, which includes the direct and indirect effects of the project on people, flora and fauna; soil, water, air, climate and landscape; material values and cultural heritage. EU Member States must have a procedure for such evaluation of projects.

Directive 2000/60/EU of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF
The purpose of the Directive is to create a framework for the protection of inland surface waters, transnational waters, coastal waters and groundwater. The directive aims to support and improve the aquatic environment
Directive 2013/51/Euratom of 22 October 2013 laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32013L0051&qid=1659362503505&from=EN
Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32008L0050&qid=1659362777881&from=EN
EU Directive 2008/50 defines air quality targets aimed at preventing, avoiding or reducing harmful effects on human health and the environment in general. Directive 2008/50/EC, despite being more “general” in nature, sets rather detailed and strict limits on pollutant emissions.
Directive 2010/75/EC of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32010L0075&qid=1659362914864&from=EN
Directive 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32015L2193&qid=1659363107329&from=EN
The directive establishes rules for the control of emissions of sulfur dioxide (SO2), nitrogen oxides (NOx) and dust into the air from medium-sized combustion plants, reducing air emissions and the potential risks to human health and the environment from such emissions. The directive also lays down rules for monitoring carbon monoxide (CO) emissions.
Council Directive 2003/122/Euratom of 22 December 2003 on the control of high-activity sealed radioactive sources and orphan sources
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32003L0122&qid=1659426652738&from=EN
Council Directive 2006/117/Euratom of 20 November 2006 on the supervision and control of shipments of radioactive waste and spent fuel
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32006L0117&qid=1659426808104&from=EN
Directive lays down a European Atomic Energy Community system of supervision and control of transboundary shipments of radioactive waste and spent fuel

Commission Recommendation 2008/956/Euratom of 4 December 2008 on criteria for the export of radioactive waste and spent fuel to third countries
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32008H0956&qid=1659427487465&from=EN
Supplements Directive 2006/117/Euratom, contains criteria for compliance with IAEA safety standards, accession and compliance with the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of 1997.
Commission Recommendation 2006/851/Euratom of 24 October 2006 on the management of the financial resources for the decommissioning of nuclear installations, spent fuel and radioactive waste
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:32006H0851&qid=1659427841803&from=EN
The Directive focuses on the adequacy of funding, its financial security and its transparency in order to ensure that the funds are only used for the intended purposes.
Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:31996L0029&qid=1659428098029&from=EN
The Directive establishes basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. The Directive contains specific limits and dose rates.