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Research Article

Export prospects of fast reactors desined in Russia with closed nuclear fuel cycle facilities

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Abstract

The inevitability of switching to carbon-free energy to withstand the climate change is no longer disputed by anyone today. There is no alternative to this, and the scientific community is forming an appropriate understanding of the need for the development of nuclear energy as carbon free energy source. Solutions are already being discussed at the level of the President and the Government of Russia. In this regard, the article shows that such a solution is possible only based on a new technological platform – two-component nuclear power with the development of technologies of fast reactors with a closed fuel cycle. At the same time the prevailing view in the public opinion of Russia, and not only in it, is that climate change problem can be solved only at the expense of solar and wind energy. This attitude needs to be changed, because without the understanding and support of society, it is impossible to achieve a wide spread of fast reactors with closed fuel cycle technologies. It is concluded that in order to promote a new technological platform in commercial energy and ensure the export prospects of fast reactors of Russian design with closed nuclear fuel cycle facilities, it is necessary to attract representatives of business circles and large energy businesses to the number of supporters of such development by demonstrating the profitability of solutions in the medium and long term, implemented in the case of the use of Russian technologies of fast reactors with the closure of the nuclear fuel cycle.

Keywords

Nuclear power, fast neutron reactors, closed nuclear fuel cycle, public opinion, environment

Introduction

Russian technologies of fast neutron reactors with a closed nuclear fuel cycle can successfully compete in the international energy market only if they have been previously and successfully used for a few years in Russia, with a demonstration of reliable, environmentally friendly, and cost-effective energy production. The term "successful" implies not only the economic attractiveness of the cost of electricity, but also the minimization of carbon dioxide emissions into the atmosphere and oxygen consumption by the entire technological cycle of fast reactors, demonstration of the provision of nuclear energy with nuclear fuel for the next few hundred years, as well as solving the problems

of high-level waste and the absence of risks of accidents requiring evacuation of the population.

Currently, the world's needs for energy development, mainly electricity production, are generally recognized and are met mainly by hydrocarbon sources. A complete transition to solar and wind energy is problematic since they have a low energy flow density[1].

At the same time, the need to protect the environment, the response to global warming and the growth of the greenhouse effect are widely reflected in the modern world scientific press. First, it should be noted the publications of the IAEA[2] and the World Nuclear Association[3], summarizing the results of numerous studies and reflecting the inevitability of the development of nuclear energy. The materials of the international conferences of the IAEA[4] noted the important role of atomic energy. Much attention is paid to methods of reducing the cost and timing of NPP construction[5]. There is a large volume of publications in scientific journals analyzing the impact of energy on the environment[6], aimed at replacing hydrocarbon energy sinks with environmentally friendly ones. At the same time, several publications quite correctly advocate the development of renewable energy sources (solar, wind, biomass energy, etc.), while a few publications favor traditional energy carriers, such as shale gas[7]. The most significant generalization of all points of view can be the words of the Director General of the IAEA R. Grossi "... We will need all low-carbon sources, including nuclear, if we want economic growth without harming the environment. The development of fast reactors is the way to the sustainability of nuclear energy. These technologies are being developed by Russia, China, India, France, the USA, Japan, and South Korea. The IAEA supports the development of fast reactors ..."[8].

The problems of energy and ecology are also relevant in Russia, which is confirmed by the position of the President and the Government of the Russian Federation[9]. Today, the Russian Federation calls on the world community to take concerted action in the fight against climate change, pointing out that nuclear energy and forest projects can be effective tools to achieve this goal, including using the podium of the 26th session of the Conference of the Parties to the UN Framework Convention on Climate Change (COP26)[10]. At the same time, it is known that the environmental characteristics of nuclear power, with the exclusion of unlikely potential severe accidents from consideration, are competitive with similar characteristics of renewable energy sources.

However, the nuclear power industry has lost its position in a few countries that previously developed it, due to problems of nuclear safety, spent nuclear fuel (SNF) management, the prospect of limiting fossil raw materials, nuclear nonproliferation and cost. Today, the leaders of the development of new nuclear energy technologies in the world are the Russian Federation and China, and the United States is making efforts to restore their lost leadership. The two-component nuclear power industry with fast neutron reactors (FNR) and a closed nuclear fuel cycle (NFC), adopted in the "Strategy 2018" by Rosatom State Corporation[11], can become the basis for energy and environmental security not only in Russia, but also in other countries.

It can be predicted that large-scale environmentally friendly nuclear power with FNR and NFC closure will become ubiquitous (Adamov et al. 2015). No other energy system can cope with the production of energy on the scale of a dozen or more million tons oil equivalent without environmental pollution (Panchenko et al. 2015; Ponomarev 2018).

Today, Rosatom State Corporation, within the framework of the "Proryv" (Breakthrough in Russian) project direction, is working on the implementation of a new approach in nuclear energy based on the BREST OD-300 reactor plant with intrinsic nuclear safety (Adamov et al. 2020). The project should also provide a solution to the problems with SNF and radioactive waste, and the formation of safe, carbon-free, renewable (considering closed

[1] Kapitsa PL (1976) Energy and Physics: Report at the scientific session dedicated to the 250th anniversary of the USSR Academy of Sciences, Moscow, October 8, 1975. Bulletin of the USSR Academy of Sciences. 1976. No. 1. pp. 34–43. http://vivovoco.astronet.ru/VV/PAPERS/KAPITZA/KAP_10.HTM (accessed 01.11.2021).

[2] Nuclear Technology Review (2020) IAEA [Electronic resource]. URL: https://www.iaea.org/sites/default/files/gc/gc64-inf2.pdf (accessed 02.02.2021).

[3] World Nuclear Association The need for large and small nuclear, today and tomorrow. World Nuclear [Electronic resource]. URL: https://www.world-nuclear.org/getmedia/b2c3bc85-deb0-4856-a5fb-3d9a5149294a/the-need-for-large-and-small-nuclear.pdf.aspx (accessed 02.02.2021).

[4] International Conference on climate change and the role of nuclear power. IAEA, Vienna, Austria, 7–11 October 2019. IAEA [Electronic resource]. URL: https://www.iaea.org/sites/default/files/19/10/2019-10-23_concluding_summary_final.pdf (accessed 02.02.2021).

[5] Gogan K, Ingersoll E (2021) The ETI Nuclear Cost Drivers Project: Summary Report. Energy Technologies Institute [Electronic resource]. URL: https://www.eti.co.uk/library/the-eti-nuclear-cost-drivers-project-summary-report (accessed 02.02.2021).

[6] Environmental impact of the energy industry. [Electronic resource]. URL: https://en.wikipedia.org/wiki/Environmental_impact_of_the_energy_industry (accessed 02.02.2021).

[7] Cooper J (2017) Life Cycle Sustainability Assessment of Shale Gas in the UK: PhD Thesis. The University of Manchester, 2017.

[8] Director General of the IAEA R.Grossi. IAEA Conference "Fast Reactors and Related Fuel Cycles: Sustainable Clean Energy of the Future" "FR22", Vienna, Austria, April 19–21, 2022.

[9] Direct line of the President of the Russian Federation 30.06.21. Vesti [Electronic resource]. URL: https://www.vesti.ru/video/2313066 (accessed 01.02.2021).

[10] The Foreign Ministry named the main tools to combat climate change https://ria.ru/20211102/mid-1757317457.html (accessed 03.11.2021).

[11] Plan for 100 years – Rosatom has adopted a long-term strategy for the development of nuclear energy. The country of Rosatom [Electronic resource]. URL: https://strana-rosatom.ru/2019/02/05/den-nauki-kruglyj-god (accessed 01.11.2021).

NFC) and stable (as opposed to the rest of the renewable sources) source of electric energy. In the context of the currently observed aggravation of environmental requirements, the spread of often unmotivated anti-nuclear phobias and anti-nuclear nihilism, the successful promotion of a new technological platform can significantly change the situation on the global energy market and provide nuclear energy with a proper place in it. This can become the basis for the export of Russian nuclear technologies.

However, for the introduction of new nuclear technology, the ability to provide it with support from both decision makers and public opinion is also of considerable importance (IAEA 2015; Gorin et al. 2020, 2021a, 2021b). At the same time, it should be understood that supporters will have to deal not only with various opponents of nuclear energy, but also with opponents within the nuclear industry who, for various reasons, oppose this direction of nuclear technology development.

This work should be carried out not only by specialists of the nuclear industry, but also by state institutions, primarily to form a popular attitude of the population to nuclear energy, first in Russia, and then in other countries, primarily in potential importing countries. An example of successful application of nuclear technologies in Russia and purposeful information work about it can stimulate their further use at home and promotion in the international energy market. The competition on it is very fierce and delay in such active actions can lead to its loss.

The main arguments of the opponents of nuclear energy

The anti-nuclear movement in various forms has a long history. The initial focus of this movement was to promote nuclear disarmament, but since the late 1960s, the rejection of nuclear energy has also been on the agenda. Now many anti-nuclear groups are against both nuclear weapons and peaceful atom. Over the past years, a set of basic theses has been formed, used by opponents of nuclear energy in their activities. The theses are summarized in the book[12], which provides arguments against the use of nuclear energy. These arguments are presented below with a counterargument by the authors of this article:

- NPP development is unlikely to affect climate change in the near future.
  That is true, in the nearest 10–20 years NPP development won't affect the climate change, since the nuclear power generation contributes only 10% of the electrical energy generated, and carbon-based energy production has been formed for tens of years and continues to dominate. The report by IEA/NEA OECD "Technological roadmap: nuclear energy" presented in the year 2015 says that in order to achieve the goal of Paris agreement, namely, not to exceed the 2 °C limited temperature rise, global NPP power generation capacity should be doubled as compared to the existing one, to reach 930 GW(e) in 2050 (OECD/IEA and OECD/NEA 2015). Only widely used NPPs in future can give some hope to the humanity to change the ecological and climatic situation and bring further improvements.
- NPP construction and operation is too expensive.
- *The statement is incorrect, since it is not clear, in comparison with what. Old NPPs, for which amortized production facilities do not require return of investments, provide one of the cheapest energy sources. According to assessments by the year 2040 in USA LCOE [13] of these stations for 1 MWh is assessed as 43$, for new NPPs – 100$, for gas-steam facilities – 65$, solar and wind generators – 50$.*[14]
- It is probable that common civilian's need for electricity is overestimated.
  That is plausible. But it seems desperate to expect voluntary self-restraint of human needs in the energy.
- The problem of waste disposal is still unresolved.
  The statement is incorrect. There are technologies allowing the one to dispose of low and medium activity wastes safely. The technologies described in the article provide solution for SNF and high activity wastes management.
- The threat of nuclear weapons proliferation and, consequently, of a nuclear war exist.
  The history shows that nuclear technologies for peace have never been used to create nuclear weapons. At the same time, nuclear industry development especially with uranium isotope enrichment and SNF reprocessing technologies add potential risks of nuclear proliferation. Besides, inherent features of these technologies combined with the IAEA assurances prevent from proliferation of nuclear weapons (Gorin et al. 2021c). Modern technical devices enhanced by computerized analysis of open-source information will immediately detect any country's attempts of clandestine development of nuclear weapons.
- Safety of this power generation technology is very doubtful.
  The statement is incorrect as it says nothing about the grounds for the doubts, neither it specifies the level of danger for this power generation technology. First of all, note that there are no absolutely safe power generation technologies. As for the nuclear energy hazard, it is the least hazardous (90, 150, 440 u 4400 – nuclear

[12] Brook BW, Lowe I (2010) Why vs Why: Nuclear Power. Pantera Press, ISBN 978-0-9807418-5-8.

[13] Levelised cost of electricity – the sum of the station costs over the lifetime, including taxes, repayments of credits, etc.

[14] An old ox makes a straight furrow. Vestnik atompromа, 2020, #5, p. 6.

energy, wind, solar panels on roofs of the houses, and gas, respectively) in terms of mortality which equals to 10^{12} Watt-hour.[15].

- There is a risk of radiation accidents.
  For today's nuclear technologies, probability of a severe accident with radiation release to the environment, i.e. the risk of such an accident is ~$3{,}7 \cdot 10^{-5}$ reactor/year (Ivanov and Hamianov 1998). For the proposed nuclear technologies, accidents that require population evacuation are out of question.

The arguments presented above, but without counter-arguments, are almost universal in nature and they are commonly found in different versions. To successfully counter them, it is necessary to understand what interests are behind the positions of certain opponents of nuclear energy. It is obvious that various categories of people who can influence the introduction of a new technological platform into commercial energy – the population, nuclear industry specialists, business representatives, politicians – have their own motives that shape attitudes to nuclear energy in general and to the prospects for its development.

The most important role in fueling anti-nuclear sentiments is played by subjective reasons arising both from conscientious misconceptions and from the selfish considerations of their carriers.

Categories of opponents of innovative nuclear energy

1. *The level of civilians*: negative attitudes to nuclear energy are created in the mass consciousness and result from the fear of nuclear accidents. This fear appears to be arbitrary, even irrational. It is fed up by the so called "leaders of public opinion". Their activities are often based on the attempts to motivate the fears referring to the research of some experts (Gorin et al. 2020, 2021b).
2. *The level of competition between different energy technologies.* Opposition to nuclear energy in this community is principally motivated by an intention to make comfortable conditions for the development of non-nuclear sectors within the energy production business. Appeal to public opinion and appropriate reference to it in communications including political authorities is typical in this case.
3. *Governmental political leadership* of the countries producing nuclear energy, as well as of those who are referred to as potential recipients. Motivation of the politicians comes from an intention not to deal with the topics that potentially intensify the struggle for voters and gives grounds for the political opponents to criticize them. For a state leader, making decision on construction of new NPPs may be risky in terms of losing voters due to proliferation of anti-nuclear attitudes. But even with enough support from the population (for example, in Indonesia) in the current situation, there is lack of confidence in economic viability of transition to nuclear energy as compared to other types of generation. This model is yet typical for almost all Southeast Asia countries. With these two factors being considered, the third one is becoming of key importance – NPP construction cycle duration. Even when the political leaders are absolutely confident in the NPP safety and efficiency, the decision on its construction does not seem quite appealing because this or that leader due to a limited term of his/her administration has little chances to succeed in getting political dividends from implementation of his/her decision. However, if any forces in this or that country (for example, big business) is interested in the nuclear energy development, the political leaders' aspirations to be supported by this force may strongly effect the role of the subjective factor in making an appropriate decision.

The opponents to innovative nuclear energy technologies from the population groups who are in principle loyal to nuclear energy may be divided in the following groups:

- supporters of alternative directions in development of the nuclear technology who consider all other options not even worthy of interest or investments;
- specialists who are not enough informed about proposed technologies and ideology;
- opponents to fast neutron reactors and SNF reprocessing technologies guided by the political concerns.

Attitudes of big electricity production companies will become critical when solving the problem of supporters/opponents to the development of innovative nuclear energy and wide commercialization of technologies discussed. In general, this group can be regarded as essentially neutral to the innovative nuclear-energy development. The people are principally motivated by the economical profit. This category, if demonstrating serious economic concerns, is capable of creating an atmosphere of positive expectations for the nuclear energy development in its new phase. These hopes can really promote practical implementation of the new technological platform based on fast neutron reactor and closed fuel cycle on an industrial scale.

From the standpoint of forming attitudes of the businessmen to new commercialized nuclear technologies, consideration of the public opinion and opinion of the political authorities, which has been derived from it in many ways, might be of practical importance. Nonetheless, motivation of the businessmen is basically subsidiary to the economic features of the innovative nuclear technologies for producing energy as compared to the other ones already used. This predetermines the need for focusing on

[15] Konk D (2021) Estimate case fatality of different types of energy: coal is at the top of the rating, and nuclear energy is on the lowest position. http://www.gazeta.ru/science/news/2012/06/14/n_2389337.shtml#t22657519… (Date of request: November 5, 2021).

economic aspects when preparing blocks of information about the proposed nuclear energy technology platform for public use.

In some cases, negative attitudes to nuclear energy results from just a lack of true information and these ideas may turn into counter-attitudes when appropriate gaps are being filled. Reasoned rebuttal by willingly misguided proponents has been recently confirmed by the story of great resonance with Zion Lights, press-secretary of international environmental anti-nuclear organization ("Extinction Rebellion" or XR). She voluntarily decided to support the nuclear energy development and announced that when she began to read about the nature and properties of radioactive wastes, she realized that she had been influenced by anti-scientific ideas and left this organization.[16]

Opponents to a new phase in the nuclear energy development based on the innovative technological approach can be categorized by their awareness level, professional training, motivation, activity, and other parameters. Due to their diversity, finely-tuned awareness raising in this area with a target of maximum efficiency among different audiences seems to be quite reasonable.

Information work

The starting point in the formation of the need for Russian nuclear technologies on the world market in general and in potential recipient countries of such technologies, it is necessary to carry out systematic information work aimed at explaining the advantages of nuclear energy and Russian nuclear technologies. In the simplest form, information should be provided designed for ordinary users who are far from nuclear energy. It is advisable to focus a more in-depth presentation of the material on representatives of civil organizations whose activities are related to energy, including nuclear, on leaders and participants of environmental and other similar movements.

A separate area of work should be aimed at highlighting the expected economic effect of the introduction of a new nuclear technology platform. Its content should generate interest in it among representatives of the energy business, indicate the potential benefits of using new Russian technologies in the energy strategy of the future.

Similarly, it is necessary to allocate materials for specialists in nuclear and radiation safety, mathematical modeling, as well as, possibly, innovative technological solutions, such as robotization of SNF reprocessing processes, etc.

A variety of options for influencing different categories of recipients of information should create a stable perception in public opinion that the world is moving towards the era of new nuclear energy, and Russia has achieved significant success in this direction. The beginning of the formation of such an idea at the stage of full readiness to enter the market with a reference product may be significantly late, which will reduce its commercial success. It is necessary to prepare the ground in advance to promote your offer at a stage when a fully finished product does not yet exist.

The task of popularizing Russian technologies of FNR and NFC closure, ensuring their positive perception by public opinion should be solved by the time they are ready to be put on the market. It is necessary to involve authorities from foreign countries in this work – scientists, entrepreneurs, politicians, etc., as was done in the world when launching campaigns on climate change, promoting environmentally friendly methods of energy production and others like that.

Working with a foreign audience

It is useful to pay attention to the activities of international pro-nuclear organizations (example https://environmentalprogress.org/) and explore the possibility of promoting information about the advantages of Russian technologies through them. In some cases, they are actively engaged in the dissemination of information that is consonant with the tasks of popularizing the development of nuclear energy, and careful interaction with them may well give a synergistic effect.

To expand the coverage and increase the effectiveness of the campaign, it is advisable to take the promotion of the concept of two-component nuclear energy beyond the purely sectoral framework. It is important that information about its benefits is available to business circles working in the energy sector, as well as to government organizations responsible for energy planning in their countries.

There are several levels of work for a foreign audience – political leadership, energy business, national nuclear energy agencies, academia, and the public. Considering the specifics of the nuclear industry, one of the most important objects of work is the IAEA. The work at each of these levels should be built considering its features both in content (different degree of detail, different set of arguments, calculation for rational or emotional perception, depending on the preparedness of the audience) and in form (from broad public events to targeted influence on leaders of political, business and scientific circles).

To ensure the constant presence of the topic of nuclear innovative technology in the information space, in addition to the scientific exchange and participation in industry exhibitions currently involved, attention should be paid to the regular publication of information materials and articles in foreign languages designed for different audiences.

It is useful to pay attention to the sites of international energy forums of a broad orientation, where it is possible to present and discuss the closed-loop NFC technology in the context of forecasting trends in the development of global energy.

[16] "The press secretary of international anti-nuclear movement has openly sided nuclear energy", June 26, 2020. Atomnaya energiya 2.0 [Electronic source] URL https://www.atomic-energy.ru/news/2020/06/26/104900 (Date of request November 2, 2021).

The needs of countries in nuclear energy

An analysis of a country's need to create a national nuclear power industry can proceed from an assessment of its energy basket and the country's intention to change it in favor of carbon-free energy sources. There are countries interested in using nuclear energy on all continents. However, the country's desire to have nuclear power in its energy basket does not mean that it intends to use the FNR with closed NFC installations on its territory. At the same time, with the competitiveness of a power unit with FNR, it can be built separately, bearing in mind the provision of its fuel cycle by the FNR supplier country.

Considering both options for exporting FNR (separately or with closed NFC facilities), it can be predicted that in South America work in this direction is possible with Brazil and Argentina as countries that already have NPPs and experience in the development of nuclear energy. In Africa, this is potentially South Africa, and in the Middle East, Saudi Arabia, which has large financial resources and plans to introduce nuclear energy at home.

Southeast Asia occupies an important place in modern world politics and economy. More than 630 million people live in the region – more than in the European Union or North America. Ten States of the region (Myanmar, Indonesia, Malaysia, Thailand, Cambodia, Brunei, Vietnam, Philippines, Laos, Singapore) are members of the Association of South-East Asian Nations (ASEAN), which has become an effective institution for maintaining political stability and security in the region.

ASEAN is collectively the seventh largest economy in the world, and according to forecasts, by 2050 ASEAN will be the fourth largest economy. According to the pace of development, the region is among the world leaders. In terms of the number of able-bodied populations, ASEAN countries rank third in the world after China and India. It should be noted the increase in the efficiency of their economy and macroeconomic stability. ASEAN has the head offices of 227 large corporations. This encourages an increase in foreign direct investment in the region. ASEAN represents a new center of consumer demand. Since 2000, the real incomes of its population have grown by an average of 5% annually, and the number of poor is rapidly declining[17].

Asia, and the region in question account for the main increase in electricity production and consumption, and energy demand in the Asia-Pacific region is projected to almost double by 2030. There is an urgent need for innovative ways to generate electricity in a socially, economically and environmentally sustainable manner. The problem is compounded by widespread energy poverty in Asia: today, almost a billion people still do not have access to electricity. In fact, Asia is the engine of global energy demand growth. China is leading in this regard, more and more India, as well as the countries of Southeast Asia. It is likely that some of them may turn to nuclear energy as an important energy resource, like China and India[18].

Although all the countries of the region under consideration are objectively interested in a large-scale increase in electricity production, including, to one degree or another, by creating their own nuclear power, the degree of their readiness to move along this path varies.

In April 2018, the ASEAN Energy Center published the "Pre-Feasibility Study on the Establishment of Nuclear Power Plant in ASEAN" (The Pre-Feasibility Study on the Establishment of Nuclear Power Plant in ASEAN), the first comprehensive study of the prospects for the development of nuclear energy in the region, prepared with the assistance of the Government of Canada as part of the Administrative Support of nuclear and Nuclear and Radiological Program Administrative Support (NRPAS). From this study, it follows that among the ASEAN members, five countries may have nuclear power in the next decade. Indonesia can launch the first nuclear power plant by 2030, Malaysia and Thailand will be ready to launch their nuclear power plants in 2035, and in the longer term the Philippines and Vietnam intend to include nuclear energy in their energy mix.

Voluntary commitments, or the so-called national contributions of the listed countries to reduce the intensity of greenhouse gas emissions by 2030 in accordance with the Paris Agreement of 2015, the achievement of which without the use of nuclear energy looks very problematic, correspond to these deadlines in general.

Nuclear energy in ASEAN structures

Nuclear technology issues are being worked out not only in individual Southeast Asian countries, but also in the general structures of ASEAN. The ASEAN Action Plan for Cooperation in the Field of Energy for 2016–2025 provides for several program areas of activity, including civil nuclear energy. Even though none of the ASEAN Member States has yet made a final decision on the use of nuclear energy in the short term, some countries have made enough progress in this direction and have expressed interest in including it in their energy mix.

Within the framework of the Association of Southeast Asian Countries, there are two bodies in charge of nuclear energy issues.

First, it is the ASEAN Energy Center. This Center, established on January 1, 1999, is an independent intergovernmental organization within the ASEAN structure that represents the interests of 10 member States in the energy sector. The Center aims to promote the integration of energy strategies in ASEAN by providing relevant information and expertise to ensure that the energy policies

[17] MGIMO MFA OF the Russian Federation. Southeast Asia is a dynamic region. https://mgimo.ru/about/news/experts/yugo-vostochnaya-aziya-dinamichnyy-region (accessed 05.11.21).

[18] Asian Development Bank https://www.adb.org/news/features/shaping-asia-s-energy-future.

of the member States are consistent with the programs of economic growth and environmental sustainability of the region. The Center is governed by a governing council consisting of senior energy officials from each State and a representative of the ASEAN secretariat.

According to the work plan, the Center performs three main functions:

1. Providing assistance to the member States by identifying and implementing innovative solutions in the field of energy policy, legal norms and technologies.
2. Support the member states in development of their energy industries by implementing appropriate programs through ASEAN.
3. Maintaining the ASEAN Energy Database and providing information to ASEAN member States.

Center also deals with the topics of civil nuclear safety, emergency response and preparedness, and improving the perception of nuclear energy in the ASEAN region. All work is carried out with broad international cooperation with foreign partners, among which China, Japan, Korea, Canada, the European Union, Germany, Norway, and the USA are the most active.

The second organization of a narrower profile is the network of organizers and regulators in the field of nuclear energy of the ASEAN countries "ASEANTOM", founded in 2013 to facilitate the exchange of best practices and information on nuclear safety, protection, and safeguards between the nuclear regulatory authorities of the ASEAN member countries. The work is carried out in the form of regular meetings of the heads of national regulatory organizations. It cooperates closely with the IAEA, but there is no information about bilateral partnership with foreign countries.

Conclusion

The two-component nuclear power industry with FNR and a closed NFC, adopted in the "Strategy 2018" by Rosatom State Corporation, can become the basis for energy and environmental security not only in Russia, but also in other countries.

The oppositional attitude to nuclear energy at the civil and political level can be changed by removing the main concerns by spreading knowledge about the advantages of a closed NFC with FNR. The work on opponents of the use of FNR and SNF reprocessing technologies among nuclear power specialists should be aimed not so much at the unlikely persuasion of themselves, as at convincing opposition to their approaches of information justifying the ideology of the "Proryv" (Breakthrough in Russian) project direction and neutralizing the influence of skeptics.

Based on the above, it can be concluded that there are export prospects for fast reactors of Russian design with closed NFC installations. At the same time, to ensure these prospects and conditions for the promotion of a new nuclear technology platform in the global civil energy sector, a line should be drawn to attract representatives of large energy businesses to its supporters by demonstrating the economic benefits of solutions implemented in the case of the use of Russian FNR and closed NFC technologies.

References

- Adamov EO, Orlov VV, Rachkov VI, Slesarev IS, Khomyakov YuS (2015) Nuclear Energy with Inherent Safety: Change of Outdated Paradigm, Criteria. Proceedings of the Russian Academy of Science: Power Engineering 1: 13–29. https://doi.org/10.1134/S0040601515130029
- Adamov EO, Kaplienko AV, Orlov VV, Smirnov VS Lopatkin AV, Lemekhov VV, Moiseev AV (2020) Bystryj reaktor so svincovym teplonositelem BREST: ot koncepcii k realizacii tekhnologii [Cooled Fast Reactorfrom the Concept to the Technology Implementation]. Atomnaya energiya 129(4): 185–194. https://doi.org/10.1007/s10512-021-00731-w [In Russian]
- Gorin NV, Ekidin AA, Nechaeva SV, Golovikhina OS (2020) Society and Atomic Industry Enterprises Information Interests: Experience of Conflicts. Public Administration E-journal 83: 47–61. https://doi.org/10.24411/2070-1381-2020-10108 [In Russian]
- Gorin NV, Abramova NL, Nechaeva SV, Golovikhina OS (2021a) Fostering Respectful Attitude towards Nuclear Industry. Public Administration E-journal 87: 6–24. https://doi.org/10.24412/2070-1381-2021-87-7-18 [In Russian]
- Gorin NV, Golovikhina OS, Glazov YE, Ekidin AA, Nechaeva SV (2021b) Awareness-Raising as a Tool in Developing the Atomic Industry. Public Administration E-journal 85: 6–24. https://doi.org/10.24412/2070-1381-2021-85-6-24 [In Russian]
- Gorin NV, Voloshin NP, Churikov YuI, et al. (2021c) Searching for Ways of Achieving Compliance with the Nuclear Nonproliferation Regime During Export of Closed Fuel Cycle Fast Neutron Reactors. Atomnaya energiya 130(1): 48–51. [In Russian]
- IAEA (2015) Collaboration with the interested parties to meet "nuclear" challenges. IAEA, Vena.
- Ivanov IA, Hamianov LP (1998) Acceptable probability and scale of a severe accident at a nuclear power plant. Atomnaya energiya 84(2): 107–113. https://doi.org/10.1007/BF02414195 [In Russian]
- OECD/IEA and OECD/NEA (2015) Technology Roadmap: Nuclear Energy. OECD/IEA and OECD/NEA.
- Panchenko SV, Linge II, Sakharov KV, Vorob'eva LM, Melihova EM, Utkin SS, Kryshev II, Sazykina TG, Geras'kin SA (2015) Radiological Situation in Geographical Areas with Deployed Rosatom Enterprises. SAM Polygraphist Publ., Moscow, 296 pp. [In Russian]
- Ponomarev LI (2018) Modern civilization doesn't have future without nuclear energy. Nuclear Expert 3–4: 70–75. [In Russian]