The Role of the Atom in Sustainable Energy Development

Svetlana Alekseevna Starykh[a], Olga Ivanovna Solodukhin[b], Natalia Evgenievna Derkach[c] and Daniil Igorevich Raspopin[d]
Federal State Budgetary Educational Institution of Higher Education «South-West State University», 94, 50 let Oktyabrya st, Kursk, 305040, Russia
cvetlana.staryx.87@mail.ru, kuznecova_olja@mail.ru, tavag5@yandex.ru, daniiltranslator@gmail.com

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Abstract: Nuclear energy has long been seen as a potential solution to meet the world's energy needs. This article discusses the benefits of using nuclear energy to ensure the sustainable development of the world's energy industry, examines the current problems associated with the use of nuclear energy, and provides an overview of potential solutions to these problems. This article provides insight into the potential of nuclear energy and how it can be realized to achieve a sustainable future..

1 INTRODUCTION

The energy sector is currently heavily dependent on fossil fuels such as oil and coal for power generation and other uses. This dependence has led to serious environmental consequences such as air pollution and global warming. Nuclear energy can play an important role in making the energy sector more sustainable.

Nuclear energy is a clean and efficient energy source and can be used to produce electricity without releasing harmful pollutants. In addition, nuclear waste can be safely stored and disposed of, making it a much safer option than fossil fuels. Nuclear energy can also be used to produce heat that can be used for domestic, industrial and agricultural purposes. It can also be used to produce hydrogen, which is a clean fuel source and can be used for transportation.

Nuclear energy can also be used to produce medical isotopes, which are used to diagnose and treat diseases. Finally, nuclear energy can be used for space exploration and other scientific research.

Thus, nuclear power not only contributes to the sustainable development of the energy sector, but can also be part of comprehensive solutions to other pressing challenges facing humanity as a whole and individual nations.

An objective assessment of the role of nuclear power in the sustainable development of the energy sector requires a detailed analysis of the advantages and disadvantages of the atom in comparison with both classical and increasingly popular renewable energy sources, and an identification of the key drawbacks, problems, and threats associated with the operation of nuclear power plants. Finally, it is necessary to propose solutions to the problems and assess the possibility of their implementation in the foreseeable future.

2 ADVANTAGES AND DISADVANTAGES OF NUCLEAR ENERGY

Nuclear power cannot exist outside of economics, politics, and society. At the moment the issue of energy in general is covered by separate aspects, such as ecology, efficiency, affordability and safety. The

[a] https://orcid.org/0000-0002-9036-7193
[b] https://orcid.org/0000-0002-8611-1320
[c] https://orcid.org/0000-0002-6362-1176
[d] https://orcid.org/0000-0000-0000-0000

ideal source of energy can stably produce huge amounts of energy in the shortest possible time, without emitting harmful impurities into the atmosphere and without polluting the environment (soil, rivers, groundwater). Of course, the ideal energy source must be safe. It is now necessary to analyze how different types of energy production relate to the ideal and through comparison establish the advantages and disadvantages of nuclear energy.

The environmental friendliness of nuclear energy has long been the subject of heated debate. On the one hand, as of 2023, public and scientific opinion habitually considers fossil fuel power plants to be an anti-example of green power. According to reports from the Russian company OGK-2, it takes about 90 tons of coal to produce 1 million kWh of electricity [1].

Depending on the power plant's capacity, it can take about 100-200 railcars of coal per day to maintain operation. In addition to enormous greenhouse gas emissions into the atmosphere, coal-fired power plants emit radioactive isotopes in the form of fine fallout, which can accumulate in soil and water over time. For these reasons, in order to realize the goals set by the Paris agreements, EU countries are actively reducing coal mining and operation of coal-fired power plants [2].

Nuclear power plants do not have the disadvantages described above. The amount of fuel consumed by nuclear power plants is considerably less, and nuclear physicists all over the world have been working for decades to study the possibility of reusing the spent fuel. Nuclear power plants do not emit greenhouse gases into the atmosphere. The biggest and still unresolved environmental problem of nuclear power plants is the need for safe storage of radioactive waste. To date, no method of safely storing large quantities of radioactive waste has been invented, and countries around the world are creating temporary landfills in remote areas or in the ocean, exposing large, albeit unpopulated, areas to radioactive contamination. For countries with small areas - such as France or Germany - storing radioactive waste on their territory is impossible, forcing these countries to negotiate costly and technically complex transportation of radioactive waste to landfills in other states.

There is a set of environmental problems of green energy, which is at the center of the EU's energy program for the coming decades. First, renewable energy power plants usually have to occupy colossal areas to ensure the generation of large amounts of electricity. The preparation of large areas requires the levelling of soil, the draining of rivers and swamps, and the felling of forests. Second, the well-known disadvantage of renewable energy - impermanence - must be compensated for by the creation of large electricity storage facilities. As of 2023, the classic solution to this problem is lithium-ion batteries, whose production causes enormous ecological damage, as evidenced every year by the ever-growing exclusion zone in the lithium triangle of Chile, in which it is either completely impossible or extremely dangerous to farm due to ecological soil pollution and soil dehydration [3].

In terms of power generation efficiency, nuclear power is superior to all other methods. For example, Russia's 11 nuclear power plants in 2021 accounted for 222244.8 million kWh of generated energy, or 20-04 million kWh per nuclear power plant on average, while.more than 2500 thermal power plants of various capacities accounted for 676908 million kWh, or 270 million kWh per thermal power plant on average [4, 5]. It should also be mentioned that NPPs are also capable of generating thermal energy, unlike wind and solar power plants.

Despite all the advantages of NPPs over fossil and renewable fuel power plants, the popularity of the former remains low in the world. One of the key reasons for this is the safety aspect. For example, in the EU countries it is impossible to locate NPPs in such a way that in the event of a nuclear disaster a significant part of the national territory would not be affected. In Russia and the United States this problem can be partially compensated by the remote location of nuclear power plants, in the small European countries such a compromise is impossible.

Nevertheless, the variability of ES power generation from renewable sources and the technological ceiling on the efficiency of transforming wind and solar energy into electricity pose significant risks to the sustainable development of energy and electricity supply. For this reason, nuclear power is strongly needed to ensure the stability of electricity supply in the future.

3 WAYS TO OVERCOME NPP PROBLEMS

There is a set of problems hindering the growing popularity of nuclear power plants in the world. The resolution of these problems requires a coordinated

and directed effort by scientists, politicians, and educators of the world.

The problem of NPP safety can be solved by introducing stricter standards, raising the qualifications of workers, and introducing new advanced solutions to individual elements of reactors and the very design of NPPs [6, 7]. It is important to have transparent and clear channels of communication between builders, supervisors, and workers in the field. Such channels will allow for effective formation of feedback from specialists and consideration of current shortcomings in future projects.

The problem of nuclear waste storage can be partially or completely eliminated by the development of fuel recycling and reuse technology. The countries of the world should develop clear and strict standards for nuclear waste storage facilities, radioactive contamination of the environment should be minimized and risks of leakage of the utilized fuel outside the storage facilities should be excluded.

The problems of the high cost of nuclear power plants and the high cost of their maintenance can be solved both by increasing the volume of components for nuclear power plants and by technological advancements. Moreover, the more NPPs are built in the world, the more rapidly component prices will fall, the more optimization solutions in designs will be applied, and the more efficient practices will be derived from the wealth of operating experience.

Probably the biggest challenge to the popularization of nuclear power plants is public and political opposition. Public opposition to the construction of new nuclear power plants is conditioned by the fear of potential man-made disasters and increased radiation background in the immediate vicinity of the plant [8, 9]. To reduce public opposition, it is important to use educators who explain to people the advantages of NPPs in a popular scientific language and explain them the anti-scientific myths about dangers of nuclear power plants. There is a need for a wide coverage of nuclear power and its safety in education and mass media.

The issue of political opposition to the construction of nuclear power plants is not easy to solve due to its multifaceted nature [10]. On the one hand, political differences between the countries can sabotage mutually beneficial projects in the field of NPP construction, a clear example of which is the cancellation of some major projects of Rosatom in the EU. On the other hand, governments may not want to depend on manufacturers of technologically complex NPP components and foreign specialists.

Finally, underdeveloped industries or small budgets in some countries can affect the profitability of building nuclear power plants and refusing to cooperate with other states in the field of nuclear energy. Only the development of constructive international dialogue, the development of lagging regions of the world, and the removal of barriers and protectionist measures in the exchange of technology can help solve the problem of political opposition to nuclear power.

4 DISCUSSION

Nuclear power is at the center of international public, political, and economic discourse. The efficiency of nuclear power plants, together with their environmental safety and absence of greenhouse gas and hazardous isotope emissions, the generation of heat along with electricity, the possibility of producing isotopes used in medicine and hydrogen that can serve as fuel for cars make nuclear power plants an attractive source of electricity. The high technological threshold required for their construction and safe operation, along with the need for safe disposal of nuclear waste and ultimate protection against man-made disasters, are significant arguments against the construction of nuclear power plants.

Public and political opposition to the development of nuclear power is multifactorial in nature. Comprehensive work on public education and constructive international dialogue can partially solve these problems.

Nuclear power serves as an excellent balance and stabilizing element for green energy due to its ability to compensate fluctuations in power generation, regular supply of particularly energy-intensive industries and urban centers, key civilian and military infrastructure. The dominance of green energy in the energy mix carries significant risks and increases the vulnerability of the state to climate fluctuations. In addition, green energy creates some environmental problems to solve others. Only a combination of green and nuclear energy can ensure both sustainable economic and energy development long into the future, and a truly effective solution to the environmental problems facing civilization.

5 CONCLUSIONS

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