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Research Article

Nuclear power in Russia's national projects*

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Abstract

Population supports the need for switching to green power, which is most often understood to mean the use of solar and wind energy. It would be however a mistake to think that solar and wind power plants will solve in full the problem of uninterrupted power supply for all sectors of economy due to the instability of generation modes and the scale of such energy production. Experts suggest that the only possible way to address global energy and environmental issues is further evolution of nuclear power. Nuclear power is not listed explicitly as a national priority project but it is a component of the Science national project and is expected to contribute to the implementation of the Ecology, Education, and International Cooperation and Export projects. In the context of the Ecology project, nuclear power is capable to play a key role in preventing environmental contamination. In the framework of the International Cooperation and Export project, it is possible to export high-technology fast neutron reactors. The experience of interaction with the interested public, and the developed and implemented occupational training programs will provide for the shaping of radiological literacy among young people as part of the Education project.

Keywords

Nuclear power, national priority projects, challenges of modern times

Introduction

The President of Russia has defined the national priority projects for the major lines of the country's strategic development; nuclear power is not listed explicitly as an individual national project but contributes inevitably to the national project implementation. The paper demonstrates the role of nuclear power in three national projects: Ecology, International Cooperation and Export, and Education. Thus, in the context of the Ecology project, nuclear power plays a key role in preventing environmental contamination in the process of electricity generation. New generations of NPPs can contribute greatly to the implementation of the International Cooperation and Export project, this to enable the export of both thermal and fast neutron reactors as high-technology products. The experience of interactions with the public gained in nuclear industry, primarily with secondary school students and young people, will promote the development of radiological and environmental literacy as part of the Education project.

The major challenge for the entire present-day civilization is the coronavirus pandemic, which has sidelined global warming and ecology issues and affected all spheres

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of human activities. As a result of the measures to reduce the coronavirus spread intensity, the industrial output and the demand for energy carriers have decreased sharply, and the transportation scale and the motor oil consumption declined, while, on the other hand, publications appeared in social media concerning the signs of the environment cleanup in large metropolitan cities due to one or even two years of such inactivity. These processes have yet to be investigated, checked for being real, and quantitatively evaluated with respective conclusions made, still they confirm the obvious thing: as soon as the intake of contaminants into the environment decreases significantly and the level of the human-caused physical impacts is reduced, the environmental situation starts to improve. The fight against the pandemic will be naturally reflected in the national projects.

Most likely, the production and contaminant discharge scales will be restored after the urgent anti-coronavirus activities are over, and an earlier and no less serious challenge, that is, global warming with simultaneous environmental impacts and their influence on human health, will return to the fore.

An international team of climate change experts has noted (IPCC 2014) that combustion of hydrocarbon energy carriers in industry, transport and households is the major cause for the global warming observed since the middle of the past century. This requires switching to green, best of all, thermonuclear power, which is capable to cope with the global energy challenges faced by the global population. In the nearest time however, this is most likely not to take place and there is no alternative for humankind than to use nuclear power (Kapitsa 1975, Ponomarev 2018, Ponomarev-Stepnoy 2016).

At the present time, there are no concurrent views about the cause for global warming (Nigmatulin 2015, Shpolyanskaya 2018), while some experts believe that, due to natural cycles, the average temperature of the ocean, the major depository of carbon dioxide, is rising and it liberates both carbon dioxide and water vapor which enhances the greenhouse effect. Humankind needs to struggle for the environment cleanup independent of the opinions and the development of green global power is the most effective way of struggle; this requires not only the general public support but also the sought-after attitude to such power and its distribution (export) by all countries. All these things reflect in the Ecology, International Cooperation and Export, and Education national projects.

Power and the ecology national project

By the beginning of the 21st century, man appears to have exceeded, approximately tenfold, the permissible level of impacts on the biosphere, and the critical point was passed about one hundred years ago (Danilov-Danilyan 2008), while humankind still lives in a paradigm that emerged thousands of years ago: the sustained growth in demands and the persisting attitude to nature as an unlimited reservoir, which makes it possible to satisfy these demands, provide raw materials and dispose of waste. Humankind will most likely have to reconsider this.

At the present time, society recognizes the pending environmental issues and hardly disputes that the key source of environmental contamination are production and use, primarily, combustion of hydrocarbon energy carriers in manufacturing, transport and households. The majority of the population supports the need for switching to green power, namely solar and wind power, erroneously believing these to solve all the problems and having no notion of the fact that the generation scale of such energy can cover just a slight portion of the global demand (Kapitsa 1975). Experts propose the only possible way to address global and, consequently, environmental issues: through the evolution of nuclear power. There is no other way for the time being but if this appears in years to come, e.g., thermonuclear power, it will take 10 to 20 years to deploy it on a mass scale. For example, it was about 20 years from the discovery of uranium fission to the first commercial nuclear plants.

The development level of modern civilization, the number of its population, and the existing material benefits have become possible thanks to industry, agriculture, medicine, education, culture, and all sciences and fields of activities whatsoever, but primarily to power. If we imaginatively take modern hydrocarbon power (and we do not have another one now) out of the life of civilization, the production volume, the size of the population, the level of living, and the life expectancy will decrease sharply. And the price of power is contamination of the environment and, possibly, an increase in the greenhouse effect and global warming.

At the present time, humankind annually produces energy carriers, largely, hydrocarbons, combusts these, and generates ~ 14.3 billion toe of energy (Makarov et al. 2016, Grachev 2019) (thermal, electric, and in the form of transport fuel) which corresponds to $\sim 6{\cdot}10^{20}$ J and ~ 19 thousand GW of power, and, therefore, there is some 2.6 kW for one inhabitant of the planet with a population of ~ 7.3 billion. It is spent both for household and, in on a multiply larger scale, for manufacturing needs. This energy is distributed extremely nonuniformly among countries, with the difference in the consumption, e.g., between Norway, Canada and Sweden, on the one hand, and the poorest countries, on the other hand, reaching a few dozen times (Fig. 1).

Power evolution forecasts are published periodically which predict particular fluctuations at a level in a range of some percent to, occasionally, as much as tens of percent but do not expect the energy generation to decrease significantly (Fig. 2) and, therefore, contamination due to the combustion of hydrocarbon energy carriers.

With each inhabitant consuming ~ 4 kW/person on the average by the time the number of the planet's population stabilizes at a level of 12 to 13 billion, the energy generation will be increased by a factor of three to four, that

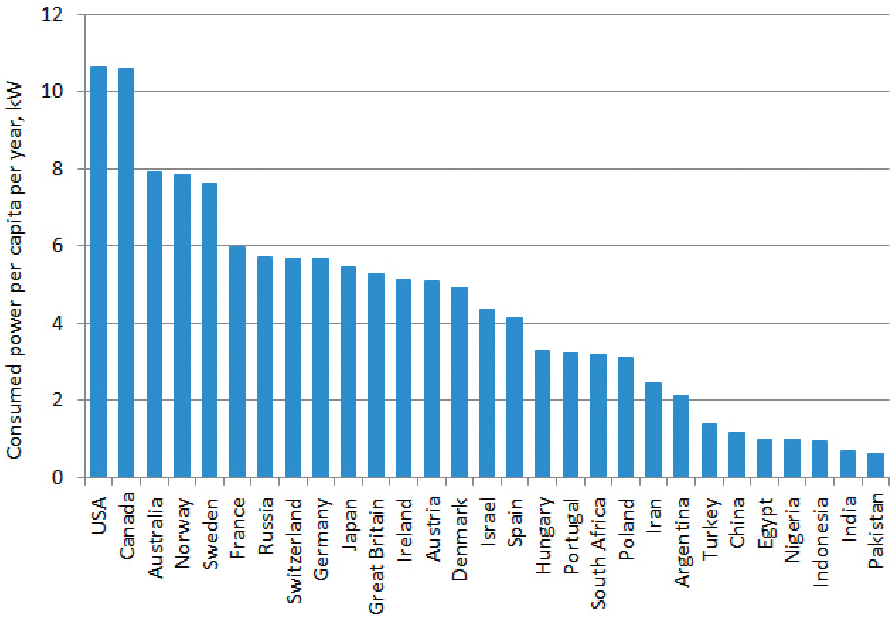

Figure 1. Per head distribution of energy consumption by countries.

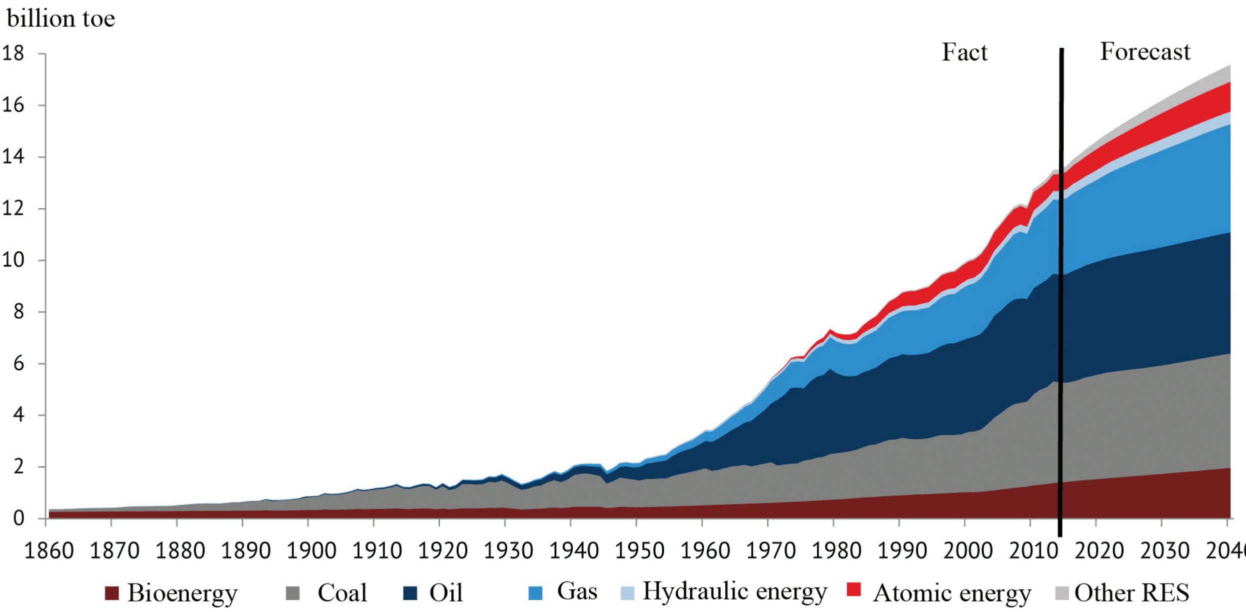

Figure 2. Dynamics of the world energy consumption by fuel types in 1860–2040 (source: Energy Research Institute of the Russian Academy of Sciences).

is, to a level of ~ (5–6)·10^4 GW. Where will this energy come from, does it exist on the planet, what will the major energy carrier be, for how long will it suffice, and can sustainable and long-term power be built based on it?

We shall formulate the requirements to the "ideal" energy technology of the future.

- It must not depend on uncertainties with fertile material supplies for at least one hundred years to come.
- The process of energy production (fuel "combustion") must not be accompanied by emission of hazardous substances or, at least, these should be in small quantities or securely localized both during normal operation and in emergencies.
- Localized waste must not be more physically or chemically active than the initial fertile material.

None of the existing energy technologies satisfies for the time being the above requirements but the nucleus of such energy technology exists; this is green nuclear power without oxygen combustion and carbon dioxide emissions.

The coal, oil, gas and uranium reserves remaining on the planet are discussed in scientific publications. Most forecasts say that the coal reserves are the largest and will last for several centuries, and the oil and gas reserves are nearing exhaustion and will last for several decades. If used in thermal neutron reactors, the uranium reserves will also last for several decades. Therefore, none of these energy carriers is fit for use as the "ideal" energy technology of the future. There are no other energy carriers however, so the only way out is to build a closed nuclear fuel cycle with fast neutron reactors, which enhances the energy resource of the available natural uranium by at least two orders of magnitude.

A two-component nuclear energy system with a closed nuclear fuel cycle based on fast neutron (BN-800, BN-1200, BREST, and others) and thermal neutron (VVER) reactor plants is a real example of environmentally friendly ways to produce energy (Ponomarev-Stepnoy 2016). It should be noted that, among the nuclear plant types used worldwide, NPPs with VVER (PWR) and BN (FNR) reactors feature as small indicators of radiological impacts on the public and the environment as possible (Desyatov and Yekidin 2018, Nazarov et al. 2018, Pyrkova et al. 2019, Yekidin et al. 2019, Yekidin and Antonov 2020). Organizational and engineering means make it possible to reduce further the impacts per unit of nuclear generated electricity (Yekidin et al. 2017). The Russian alternative two-component nuclear energy system based on NPPs with PWR and CANDU reactors will feature greatly increased impacts on the public and the environment due to the tritium emissions and dumps, specific for CANDUs, being two orders of magnitude as high as for any other NPP reactor types (Yekidin et al. 2016, Desyatov and Yekidin 2018). All other methods of energy production in the amount of over 10 billion toe (it is exactly that much that humankind consumes today) will not cope with this task without environmental contamination.

The evolution of nuclear power in Russia and worldwide contributes to the implementation of the Ecology national project.

Power and the international cooperation and export national project

Energy carriers are currently the key products at international markets. It is quite possible that the use of coal, oil and gas will be reduced in several decades, that is, for the lifetime of two or three generations, e.g., due to depleted resources, or will even be legally limited at the national or international level because of environmental threats. Uranium remains then the only energy carrier but not for the open nuclear fuel cycle based on uranium-235 but based on uranium-238 in a closed cycle using fast neutrons in the reactors.

By now, the nuclear industry has generated some 1 million tons of nuclear grade uranium hexafluoride, which should be considered as the "strategic reserve" and the raw material for the future power rather than waste. The value of this reserve should be expressed not in monetary units, which may change depending on certain historical events, but in absolute energy values, which are invariable in principle. At the present time, as noted above, humankind generates 14.3 billion toe ($6 \cdot 10^{20}$ J) of energy annually, and it can be computed that the accumulated uranium contains energy in the amount exceeding by two orders of magnitude the annual demand of humankind. Therefore, uranium hexafluoride is an already ready source of uranium for fast neutron nuclear power and future generations will get an already ready energy carrier, which contains energy to suffice for a hundred years. It is not greatly needed today since uranium-235 has largely been extracted from it, but uranium-238 will be in demand in several decades as nuclear power with fast neutron reactors and a closed nuclear fuel cycle is started. It will not only provide the country with energy for a number of decades but will also make it possible to sell uranium to other countries, including together with reactor plants and the onsite fuel cycle.

At the present time, Rosatom State Corporation exports Russian VVERs and, in most cases, the export conditions provide for the repatriation of spent fuel to Russia for processing, and the importing country does not have access to the Russian nuclear material. Rosatom plans to enter the international market in 10 to 20 years with fast neutron reactors and technologies of a closed nuclear fuel cycle, which potentially offers such access, and Rosatom has therefore initiated the development of the export conditions as a nonproliferation safeguard.

All this contributes to the evolution of the International Cooperation and Export national project.

Radiological and environmental literacy and the education national project

Experts propose the only possible way of addressing global energy and, therefore, environmental problems, that is, through the evolution of nuclear power, but, after the Chernobyl and Fukushima accidents, the general public attitudes to this are for the time being wary though not altogether expressly unfriendly. However, there is little tacit support for nuclear power now since environmental problems are increasing too rapidly and it is already the sought-after attitude of society to its evolution that is required, this expected to promote an extensive evolution of nuclear power with fast neutron reactors and a closed nuclear fuel cycle. More than that, the next step shall be society's shaped requirement for the evolution of nuclear power and nuclear technologies.

Public opinions are conservative and change slowly for the better, so the most effective way to shape the sought-after public attitude to nuclear power and to raise the radiological and environmental literacy is then to work with secondary school students and young adults (Gorin et al. 2018a, 2018b, 2019), whose conservatism is minimal and who, the most important thing, will be setting trends for the country's development in 10 to 15 years. One of the educational issues is concerned with their poor radiological (Gorin et al. 2018b) and environmental (Abdrakhimov et al. 2016) literacy and, consequently, of the population at large which is a point of concern for experts. Thus, after the Chernobyl disaster and the Fukushima accident 25 years later, two consecutive generations of people were asked, as part of public opinion polls, one and the same question about the number of those killed by radiation impacts as the result of the accidents where both generations answered wrongly saying there were hundreds, thousands, and even millions, while, actually, there was none at Fukushima and very few people died in the course of the accident response activities at Chernobyl (Panchenko et al. 2015). Several years later, the Chelyabinsk Branch of the Russian Academy for National Economy and Public Service held an opinion poll on the attitudes of the Chelyabinsk Region's population to nuclear power asking a question concerning the evolution of nuclear power in the region. The results showed (Ilyinykh et al. 2018) that a small portion of the population (11%) saw "nothing bad" in it, as most of those polled (89%) were afraid of accidents, the contamination of the territory, and a growth in the radiation level. The answers confirmed that the population remained, as it had been, unaware of radiation ecology issues and, most likely, due to not having been educated in this at school. It should be however noted that most of the public in residential areas, where the NPP is the city-forming enterprise, support the industry and the evolution of nuclear power which can be explained by their greater radiological awareness.

The attitude of society towards nuclear weapons, the nuclear legacy of the cold war, and nuclear power have continuously been of interest to different experts and, specifically, it was noted in one of the latest publications by historians (Melnikova et al. 2018) that:

"*... Active supporters and opponents of nuclear power are clear minorities in Russian society. Most of it is somewhere between the unequivocal negation of nuclear power as such and the attitude to it as a promising and sustainable way of power supply.*"

Young people (secondary and higher school students) have not yet taken sides but they will inevitably do this in a number of years after graduation and will start to play a growingly important role in the country's life, so it is now that the struggle for their way of thinking needs to be started, including as part of the Education national project.

The evolution of nuclear power in conditions of the public being skeptical about and, more than that, negating it will be difficult and expensive since it will be required to overcome the public opposition and, possibly, deploy installations in inhabited locations making so the construction and energy much more expensive. One of the measures to reduce the public skepticism is through awareness campaigns for improving the radiological literacy to contribute so to the implementation of the Education national project. To this end, Rosatom is undertaking public outreach activities for the population and young people, including as part of the Education project, building fast neutron reactors with a closed nuclear fuel cycle contributing in such a way to the Ecology project implementation, and setting up conditions for exporting them and safeguarding their leadership in 2030–2040.

Therefore, nuclear power, which is not listed as an independent national priority project but is a component of different national projects, such as Science, contributes substantially to the implementation of the national projects.

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