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# Nuclear Renaissance: A View From Russia

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The first nuclear electricity obtained in a US laboratory in 1951 and the first nuclear power plant built in the Soviet Union in 1954 both marked the beginning of the era of the peaceful atom.

In the years since then, a huge amount of knowledge and technological experience in the development, construction and operation of nuclear power installations of various types, as well as of nuclear fuel cycle enterprises, has been accumulated. The total number of nuclear power installations built in Russia alone exceeds five hundred, with the majority of them representing the light-water reactor concept – the most widely developed in the world.

Scientists and designers have considerably extended the limits of the reactor facility parameters: reactors with unit capacities up to 1500 MWe have been developed and implemented; nuclear reactor uses for heat supply and water desalination have been tested; nuclear facilities with direct energy transformation have been developed; the possibility of the long-term autonomous operation has been proved (in space); the exclusive resistibility of the reactor installations to percussive loads has been demonstrated (on sea); and unique fuel compositions and reactor materials which have proven their ability to work at temperatures up to 3000 K have been created.

Two phases can be clearly distinguished in world nuclear energy development.

The first phase – which is still continuing – is a phase of evolutionary development of nuclear technologies initially created for military purposes, based on thermal reactors using relatively cheap uranium and the once-through fuel cycle. This phase has demonstrated the possibility and advantages of the industrial use of nuclear power.

In the field of nuclear energy production, some countries have reached a convincingly enhanced competitiveness thanks to improved NPP operating parameters, and, in particular, capacity factors. In the United States, half of its three-fold growth of nuclear electricity production in the last 20 years was achieved as a result of these factors. Similar processes have also been developed in recent years in Russia, where a 30% nuclear generation growth at the country's operating NPPs is equivalent to the commissioning of five 1000 MW units.

 

A large scientific and technological reserve has been created in the field of advanced reactor systems and fuel cycles, including those making possible efficient utilisation of accumulated plutonium. Possibilities for uranium and thorium fuel cycles with extended breeding have also been studied, thus paving the way for the use of practically unlimited fuel resources. At the same time, Russia is the only country in the world which operates a commercial fast neutron reactor.

The current phase of nuclear power development has confirmed the viability of nuclear energy. The key technical problems have been identified. The principal ways of their solution are already known, and, after their implementation in this century, the beginning of the *new phase* of nuclear energy use – *large-scale nuclear power development* – will become possible.

Its specific features are:

- use of nuclear reactors having practically no fuel resource limits;
- economic competitiveness due to the reduction of NPP construction and service costs, high efficiency of the nuclear fuel and long operation lives;
- elimination of severe accidents with radioactive releases, which would require the population's evacuation – mainly using the inherent safety systems;
- environmentally safe closing of the nuclear fuel cycle including the burning and transmutation of actinides and hazardous long-lived fission products.

### Russian re-estimation of the role of nuclear energy

Following the occurrence of a long-expected event in the Russian economy in 1999 – the start of growth in energy demand (after a 15-year decrease) – in the coming years another important change in the economy is expected: Russia, for the first time in the recent decades, will face a growing electricity deficit.

The structure of Russian primary energy production and consumption is considerably biased towards natural gas (about 49%), with a much lower rate of coal use (14% in production and 19% in consumption) and of oil use (33% production and 22% consumption). Nuclear, with hydro and other renewables, provides only 10% of national consumption. At the same time, in 2000 Russia exported 60% of its national energy resources.

Certainly, in the coming decades, the Russian energy infrastructure – as well as the global one – will still be based on fossil fuels and traditional energy technologies.

However, today's 'pre-crisis' situation in the Russian fuel and energy complex – masked until recently by falling consumption – is just the result of the previous long phase of rapidly growing extraction and consumption of the country's abundant energy resources, when for many years funds were invested in developing the power industry without sufficient reproduction of the infrastructure.

Russia's natural resources represented a sort of a hampering factor in its development and prosperity, making it possible to apply the 'easy' decisions in difficult situations, i.e. relying on the extraction of resources and increases in consumption.

No new cheap fossil fuel resources should be expected in Russia in future. The rate of cost-effective exhaustion of reserves at the country's exploited oil deposits has exceeded 50%. The times have passed when giant deposits were found which provided both growth of reserves and decrease of prospecting and extraction costs. The growth of proved reserves in recent years does not cover the current oil extraction.

Basic gas deposits in Western Siberia have reached the stage of decreased output and are more than half exhausted. In order to maintain only present extraction output for the period to 2020, as a minimum, a three-fold increase of investments in the development of new gas deposits in the circumpolar zone and at the northern shelf would be necessary.

Projected decreases in natural gas extraction in Russia, as well as the 'degasification' of the power industry, which has already started, will require alternative sources to cover the gap in the primary energy resource base, especially coal. However, coal is actually a regional fuel resource, and constraints on the ability to get it to the European region of Russia will inevitably conflict with the possibilities provided by the transportation system, resulting in the transition to other kinds of fuels. Moreover, growth in coal consumption will strongly depend on evolving environmental restrictions.

The increasing rate of exported fossil energy resources (which could be further promoted by their partial substitution in national energy consumption) is another very important feature of the Russian fuel and energy complex. It should be noted that in the case of a considerable increase in exports, the potential for a crisis impacting the country's economy would become much stronger. In the next two decades, the increase of Russian supplies to external markets should be restrained.

The understanding of the need to apply anti-crisis measures to the country's economy – both by government leaders and by the science and industry elite – has led, at the turn of the century, to a considerable re-estimation of the role of nuclear energy, which, previously, had been severely restrained both by the economic situation and by post-Chernobyl political pressure.

It is now generally recognised that, in the short term, nuclear power – which has guaranteed fuel resources for the coming decades even on the base of the currently available technologies – may become *a stabilizing factor in the power industry*, operating, moreover, in an environmentally safe manner.

The first results of this reconsideration of nuclear power policy can be indicated already:

- The improvements in the use of existing capacities referred to above has made it possible, in just three years, to increase annual generation by 30 billion kWh;

- In 2001, for the first time in the last eight years, a new nuclear unit was commissioned in Russia, thus opening the way to an expected series of plant completions on nuclear construction sites which had been halted by Chernobyl and economic dislocation in the post-Soviet period. Work on another nine sites is underway, with the target of launching the new units by 2010;
- For the first time in the Russian nuclear industry, a 5-year operating life extension licence (with the possibility of a 15-year extension) was granted, and similar work is underway for another nine units;
- Five 1000 MW units are being built abroad;
- Work on the new projects has been started: the fast neutron reactor BN-800 and the floating small co-generation plant, based on naval nuclear reactors.

Quite apart from the feasibility of these plans and the projections of the further developments, it should be noted that the political will of the country's leaders to develop nuclear power has been demonstrated both by their international statements (at the UN Summit) and by the government's own programme documents ('Strategy of the Russia's nuclear power development in the first half of the XXI century').

The adoption of the portfolio of the Russian laws aimed at legalising services for the storage and reprocessing of foreign nuclear fuel – which was without doubt a difficult political decision for the country's leaders – is indicative of *a serious and long-term recognition*, at the highest Russian governmental levels, *of the need for the development of nuclear power.*

The new US energy doctrine, which practically coincided in time with Russia's reconsideration of its nuclear strategy, and which considers nuclear energy as 'a major national policy component', has made it objectively possible to intensify rapidly cooperation between the two 'pioneers of the nuclear era' in the area of the long-term use of nuclear energy. This happened immediately after the May meeting of the two countries' presidents.

The joint group of experts created at the presidents' instigation has recently submitted to the two presidents its proposals for cooperation between the United States and Russia in the field of advanced nuclear reactor and fuel cycle technologies, as a part of a joint strategy aimed at improving energy reliability, as well as the economies of the two countries.

**The global nuclear future**

The similarity of the near-term Russian and US nuclear energy plans is well known. They are based on the advanced pressurized water reactors (AP-1000 and VVER-1000 and -1500, respectively) and a common interest in high-temperature gas-cooled reactor technology. According to some estimates, given government support and appropriate economic conditions, nuclear power could meet up to 50% of US and 40% of Russian electricity demand by 2050.

Strategic perspectives – in the form of promising international programmes – are being developing independently at the moment.

Russian specialists participate in the INPRO project initiated by Russia in the IAEA and having the goal of 'uniting the producers and users of nuclear technologies from all the member countries in order to jointly consider the measures which should be taken at the international and national levels for realisation of innovative nuclear reactor and fuel cycle approaches, ensuring competitiveness and security based on inherent safety systems, as well as reducing the risk of nuclear arms proliferation and negative impact on the environment'.

At the same time, several countries, following the initiative put forward by the US Department of Energy within the framework of the programme 'Generation IV International Forum' (GIF), are exploring the possibility of creating reactors capable of ensuring a competitive cost for electricity, minimising the risk of accidents involving core destruction, reducing the financial risks of investments in NPP construction and of enhancing the resistibility of nuclear energy to nuclear proliferation. The programme provides for the development of several nuclear power systems suitable for implementation in both developed and developing countries starting from 2030.

The IAEA international project INPRO and the GIF project are not at all contradictory; on the contrary, they are mutually supportive and – taken together – cover the main goals of short- and long-term nuclear energy development, the creation of large NPPs for large power systems, as well as autonomous low- and medium-capacity sources of electricity generation and nuclear fuel cycle facilities.

These projects, in their development of new nuclear energy technology complexes, will certainly help to reduce the pressures caused by limited oil production capacity, for example, through the use of high temperature nuclear technologies for generating hydrogen (‘nuclear hydrogen energy’), and also through water desalination.

The possibilities for a Russian contribution to world nuclear development are illustrated in *Table 1*, which compares the reactor concepts selected for further study within the GIF framework (by June 2002) with the available Russian technological experience. It can be seen that all the preconditions exist for cooperation in the field of long-term nuclear energy development, innovative nuclear reactors and fuel cycles.

Accumulated world experience provides the basis for the feasibility of large-scale global nuclear power development. Now is the time for the major nuclear countries to develop a joint initiative that will define the new nuclear era and assure the extended use of nuclear technologies which will indeed contribute to global energy security.

These countries should join efforts in developing a fuel cycle system for the future that can be shared with the developing world by using reactor-lease agreements and cradle-to-grave supply contracts. This could reduce the increasing global competition for finite resources and dependence on unstable energy exporting regions, and allow the non-nuclear weapon states to share in the consumption of nuclear warheads and the beneficial use of other by-product materials left over from the Cold War.

For the long term, the idea of creating a limited number of large nuclear fuel cycle centres, based on the technological experience of the leading nuclear states, should be considered. These centres could manufacture nuclear equipment and fuel, as well as carry out leasing-based supply to other countries throughout the world, with the by-products being returned for processing, leading to conditioning and minimisation of waste. The nuclear energy technology complexes in these large nuclear centres would be subject to international control.

Such an approach to the organisation of the global nuclear infrastructure, in our opinion, would completely satisfy requirements for preventing nuclear arms proliferation, while keeping access to nuclear energy sources open for all countries of the world.

Most of the energy industry's strategic problems have a long-term character. The ability of private investment to provide long-term solutions is limited because of their global character and the existence of the high economic risks, especially in light of the current trend towards globalisation of the energy sector. Only governments can formulate policies and invest in the technologies necessary to manage these risks over the long term. The creation of an investment climate which supports private capital's involvement in the solution of energy problems will be an important part of these policies.

Free market mechanisms ensure efficient use of current resources, but they do not guarantee sustainable development for future growth in energy needs. In the twenty-first century, mankind will live in conditions of swift technological and social change. In order to ensure sustainable world-wide development, large and long-term capital investments in the global infrastructure (beginning with the energy infrastructure) will be required to support global economic growth.

It will be necessary not only to overcome limitations in global resources, but also to develop national and world energy development strategies that will ensure the sustainability of energy supply systems and the flexibility of nations to react to the continuous changes in the technological and economic situation expected over the next century.

To achieve this, the leading powers must create a stable energy nucleus which is less sensitive to the destabilising factors in world energy. From the existing technological options, nuclear energy best satisfies these requirements. Nuclear energy could play a stabilising role in periods of transition and in crisis situations thanks to the high level of independence in the character of size of the nuclear fuel extraction and production infrastructure. The proportion of nuclear energy in the total fuel and energy complex, and even in electricity production, is not very large, but it may turn out to be important for energy resource price stabilisation and for economic development as a whole. The development of nuclear energy requires considerable long-term investments, but in the long term, their efficiency will grow steadily.

Given the events unfolding at the start of the new millennium, and some 50 years after the Eisenhower Atoms for Peace Programme, a new *Atoms for Peace and Prosperity* programme could now be launched.

Such a proposal was, in fact, included in the joint report prepared by the Sandia National Laboratories (USA) and the Kurchatov Institute (Russia) for the May Summit of the US and Russian presidents.

**Table 1. International project Generation-IV and Russian technology experience**

| **GENERATION-IV**<br>(June 2002) | **RUSSIA** |
|---|---|
| ***Thermal systems*** | |
| **Supercritical Water-Cooled Reactor**: | |
| • 1700 MWe.<br>• 500°C outlet temperature.<br>• Efficiency near 45%. | • 20 years of R&D, including the reactors with variable neutron spectrum, with up to 1800 MWe capacity.<br>• Works stopped at the beginning of the 1990s. |
| **Very High-Temperature Reactor**: | |
| • 600 MWe.<br>• > 900°C outlet temparature.<br>• 1250°Ñ fuel temperatures.<br>• Solid graphite block core based on GT-MHR. | • 30 years of R&D.<br>• Existed an operational prototype with outlet temperature of 3000 Ê.<br>• NPP technical projects (ABTU-50, VG-400 with temperature of 950°Ñ).<br>• International GT-MHR project is being developed.<br>• PBMR development is supported. |
| **Molten Salt Reactor:** | |
| • Fuel – liquid Li, Be, Th, U fluorides.<br>• 1000 MWe.<br>• low pressure (< 0.5 ÌÐà) and high temperature (> 700°Ñ). | • 30 years of R&D, including fluoride technologies, physics and chemistry of the molten salt fuel, loop and reactor tests, etc. |

| *Fast systems* | |
|---|---|
| **Sodium-Cooled Reactor with Advanced Recycle Technology:** | |
| • 150 to 500 MWe.<br>• Metal fuel with metallurgical recycle or 'pyro'-process. | • 50 years of R&D, several reactor prototypes.<br>• 20 years of operating a BN-350 plant with desalination.<br>• In operation: the world's only commercial NPP with fast BN-600 reactor. Under construction: NPP with BN-800 reactor.<br>• Development of BN-1600 reactor was stopped in 1992.<br>• Research, development and reactor tests both of the traditional oxide fuel and the 'dense' fuel (metallic, based on carbides and nitrides).<br>• Gas-fluoride and chloride technology of the fuel pyro-chemical processing reached the stage of pilot facilities. |
| **Fast Lead-Bismuth-Cooled Reactor**: | |
| • 120-400 MWe.<br>• 540 to 750°Ñ outlet temperature. | • 30 years of R&D, existed operational prototypes with total operation time of 80 reactor years. |
| **Fast Gas-Cooled Reactor**: | |
| • 600 MWth / 288 MWe.<br>• Íå – coolant.<br>• 48% efficiency. | • 20 years of R&D.<br>• Works stopped at the beginning of the 1990s. |
| **Fast Lead-Cooled Reactor:** | |
| No proposals. | • 15 years of R&D.<br>• Technical design of the demonstration unit is being developed. |

| *Small systems* | |
|---|---|
| No proposals. | • 40 years of R&D. Hundreds of existed and presently operating ship facilities with water-cooled reactors.<br>• Several NPP prototypes, including an operational one (Bilibino).<br>• About 20 NPP designs with water-cooled and lead-bismuth reactors.<br>• Construction-ready design of a floating NPP with KLT-40 reactor. |