THE CASE FOR IMPROVING THE TECHNICAL AND ECONOMIC PARAMETERS OF FR SMRS IN RUSSIA

21st INPRO Dialogue Forum on the Deployment of
Small Modular Reactor Projects and Technologies to Support the Sustainable Development Goals (SMRs for SDGs)

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Andrey Kashirsky
Head of Analytics
JSC “Proryv”
Motivation for increasing nuclear power share in Russia's energy balance

- Achieve target indicators of the Strategy for Socio-economic Development (SED) of the Russian Federation with a low level of greenhouse gas emissions by 2050;

- Improve ecological indicators in regions with a high share of coal generation;

- Support the competitiveness of Russia's export products by increasing the share of carbon-free electricity used in production;

- Conserve natural gas as a valuable resource for domestic and international markets.

The value of natural gas for Russia

Report of the Ministry of Natural Resources on the state and use of mineral resources in the Russian Federation:

• Russia is the world's leading exporter of gas

• One-third of the natural gas extracted in the country is exported.

• Russia possesses the world's largest raw natural gas resource base, with its recoverable reserves exceeding 70 trillion cubic meters.

• The gradual depletion of the most profitable natural gas reserves in traditional onshore regions and the shift of gas extraction to remote and challenging regions necessitate the creation of new extraction and transportation infrastructure.

UES – Unified Energy System

• Power plants fueled by natural gas and coal continue to dominate the energy balance, representing approximately 66% of the total installed capacity of the power system.

• Low share of renewable energy in Russia (no prerequisites for its significant increase).

• Nuclear power plants in Russia account for 12% of the total installed capacity and generate 20% of the electricity produced.

UES installed capacity at 01.01.2022

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Capacity (GWe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuels</td>
<td>163</td>
</tr>
<tr>
<td>Hydro</td>
<td>50</td>
</tr>
<tr>
<td>Nuclear</td>
<td>29,5</td>
</tr>
<tr>
<td>Wind</td>
<td>2</td>
</tr>
<tr>
<td>Solar</td>
<td>2</td>
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</tbody>
</table>
Nuclear power capacity development outlook (Strategy-2021)*

Target objective:

- Increase the share of nuclear energy in electricity generation in the country to 25% by 2045-2050

Main tasks and challenges:

- Reduce CO2 emissions per kilowatt-hour generated by Russia’s power industry;
- Reshape the current nuclear power fleet structure into a two-component system;
- Develop closed nuclear fuel cycle facilities;
- Expand the reach of nuclear power and provide low-carbon energy to isolated and hard-to-reach territories.

* Russian Nuclear Power Development Strategy to 2050 and beyond until 2100.
Fossil fuel replacement potential

14 Gwe are plants with installed capacity < 2 GWe

Based on Energy Research Institute of the Russian Academy of Sciences data
Nuclear energy technologies within the «Development of Engineering, Technologies, and Scientific Research in the Field of Atomic Energy Use in the Russian Federation» framework

BREST-OD-300
- Fast neutron reactor with lead coolant
- On-site closed nuclear fuel cycle
- Practical demonstration of the new technological platform
- Under construction in Seversk (Tomsk region)

VVER-S
- Medium-power reactor with neutron spectrum control
- High maneuverability
- Can operate with 100% MOX fuel
- Planned as an export product

Large fast neutron reactors
- Sodium cooled BN-1200M planned at the Beloyarskaya NPP by 2035.
- Lead cooled BR-1200 planned for large-scale FR deployment
- Foundation for transitioning to a two-component nuclear structure
- Use U-Pu fuel as a renewable resource.
- Transmutation of minor actinides.

Small NPPs
- RITM-200, FNHPP, SHELF, ELENA
- Ideal for isolated and hard-to-reach areas
- Designed to meet industrial needs and medium-sized settlements
- Electricity and heating for small consumers
- High export potential
Pilot-demonstration energy complex with the BREST-OD-300 reactor

Demonstrating the fundamental possibility of closing a nuclear fuel cycle based on "inherent" safety principles.

U-Pu production facility

Construction site
Pilot-demonstration energy complex objectives

- Consists of three key elements – a nuclear power unit with BREST-OD-300, a nuclear fuel fabrication/refabrication module, and a nuclear waste treatment module.

- Uses mixed nitride uranium-plutonium (MNUP) fuel.

- Implements an on-site (local) nuclear fuel cycle.

- Will verify the operability of the closed nuclear fuel cycle technological chain for the creation of large commercial reactors.

- Will confirm the possibility of recycling nuclear fuel (with minor actinides) to achieve conditions for radiation-equivalent disposal of radioactive waste.

«First concrete” ceremony for the construction of the BREST-OD-300 in 2021.
SMRs - paradigm shift or tailored for specific purposes?

IEA, Energymonitor.ai
Main issue with large-scale SMR deployment

• NuScale and the Utah Associated Municipal Power Systems (UAMPS) announced costs of a 462-megawatt small modular reactor (SMR) have risen dramatically.

• As recently as mid-2021, the target price for power was pegged at $58 per megawatt-hour (MWh); it’s risen to $89/MWh, a 53% increase.

• The price would be much higher without $4 billion federal tax subsidies that include a $1.4 billion U.S. Department of Energy contribution and a $30/MWh break from the Inflation Reduction Act.

• The higher target price is due to a 75% increase in the estimated construction cost for the project, from $5.3 to $9.3 billion dollars.
To increase the role of nuclear energy in the small-to-medium power segment, we propose developing hybrid nuclear systems that utilize fossil fuels to superheat steam before the turbine of the plant.

The gas portion of a conceptual heat balance diagram of a system like this would consist of a single natural gas boiler that would mainly include steam superheaters and air preheaters. The rest of the system would not fundamentally be different from the standard thermal scheme of a nuclear power plant.

**Overall objective – take into account the availability of fossil fuels (natural gas for Russia) in the region and use it to increase the steam temperature before the turbine and enhance the efficiency of the system**
### Major differences in equipment

<table>
<thead>
<tr>
<th>Наименование оборудования</th>
<th>Conventional NPP (mid-size)</th>
<th>Hybrid system (gas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-pressure heaters, units</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Low-pressure heaters, units</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Separator</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Natural gas boiler</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Superheater</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Air preheater</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Steam turbine</td>
<td>1 (300 MWe)</td>
<td>1 (over 480 MWe*)</td>
</tr>
</tbody>
</table>

* Preliminary assessment
Hybrid systems based on medium-power nuclear powers with superheated steam could be competitive with traditional fossil fuel generation.

The possibility of utilizing existing infrastructure of thermal power plants should be considered taking into account specific site characteristics.
Conclusion

• Without the widespread development of nuclear energy, achieving the national climate goals set by the Russian government hardly possible.

• "ROSATOM" is developing a wide range of solutions to strengthen the presence of nuclear energy in the energy markets of Russia and abroad, relying on the country's internal intellectual and material resources.

• For many regional power systems, the construction of large-scale nuclear power plants (>1000 MW) is not feasible. An optimal solution may be a medium or even small-scale nuclear power plant.

• The internal efficiency of a conceptual hybrid nuclear power plant utilizing natural gas to superheat the steam before the turbine is estimated to be over 50%.

• The power of the steam turbine can be increased by about 1.6-1.7 times through additional steam superheating

• Decisions on the configuration of nuclear power plants that enhance the efficiency of nuclear energy should be further developed and justified when considering specific plant locations with the involvement of relevant stakeholders.
Thank you!

Andrey Kashirsky
Head of the Analytical department
JSC “Proryv”
E-mail: kana@proryv2020.ru
www.proryv2020.ru