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A new technological platform for global development of next generation nuclear power

International Conference on Fast Reactors and Related Fuel Cycles: Sustainable Clean Energy for the Future (FR22)

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FR-17 conference

Hosted by the Government of the Russian Federation in 2017 through State Atomic Energy Corporation ROSATOM

Attended by more than 550 participants from 27 countries and 6 international organizations

The conference highlighted the commissioning of the BN-800 sodium cooled fast reactor in 2016 at the Beloyarsk Nuclear Power Plant (NPP), located in the vicinity of Yekaterinburg.

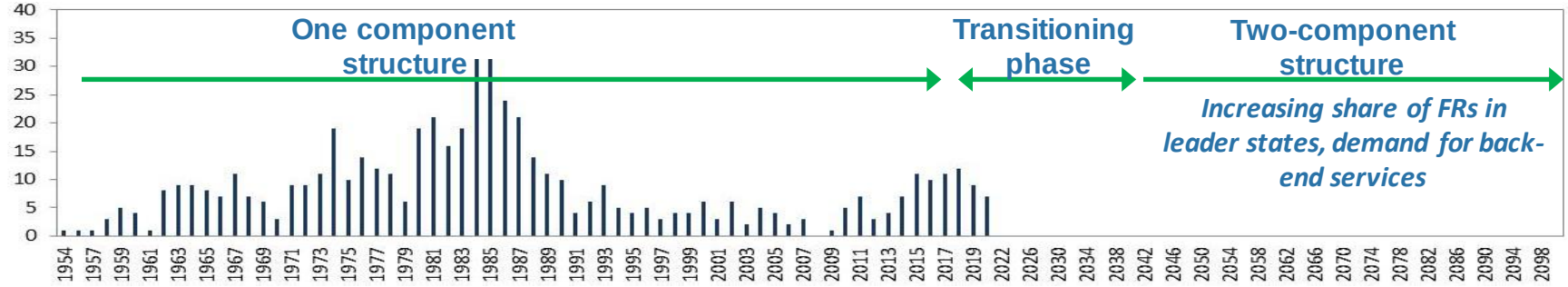
Major advances in several key areas of technological development were presented during the conference at 47 technical sessions, by approximately 200 oral presentations in eight parallel technical tracks.

Fast neutron reactor systems, operated in a fully closed fuel cycle, have the potential to significantly increase the sustainability of nuclear power. They can extract 60 to 70 times more energy from uranium than existing thermal reactors and reduce the volume and toxicity of the final waste. They will be both safer and more efficient than current reactors.
- Yukiya Amano, Director General, IAEA

Transitioning to a two-component nuclear power structure

A demand for increased competitiveness and safety for nuclear power projects incentivizes the transition to a two-component nuclear structure: thermal reactors + fast reactors

Russia is on track to make this transition possible at scale



SNF management status

I Stage
SNF – valuable resource

Significant growth of global NPP capacity highlighted by the 1970s energy crisis. Concerns regarding natural uranium supply. Several projects aimed at SNF recycling underway to lower dependence on natural U.

II Stage
SNF – waste

Improvements made mostly at the front-end on the NFC. SNF management strategy for most countries reduced to interim storage for an indefinite time period

III Stage
A demand for closed NFC solutions

Gradual minimization of overall SNF.
No practical limits to resource base.
No deep geological disposal of SNF.

The foundation for closing the nuclear fuel cycle

The main elements of the NTP are fast reactors and closed nuclear fuel cycle technologies (FR+CNFC).

Russia has vast fast reactor operation experience with plans to expand its FR fleet in the future. Two FRs with a sodium coolant are currently in operation – the BN-600 and BN-800).

The BN-800 now currently running on 60% MOX fuel. The plutonium for this was produced from uranium during the operation of other nuclear power plants and recovered from the used fuel assemblies through reprocessing.

This marks the first step in effectively closing the nuclear fuel cycle in Russia using thermal and fast reactors.

The reactor achieved a capacity factor of 82% despite having an experimental role in proving reactor technologies and fuels.

Unit 4 of the Beloyarsk NPP

BN-800 reactor

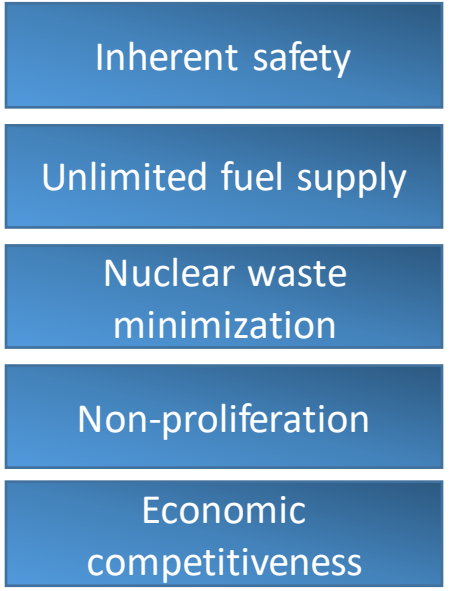
A new technological platform for nuclear energy

Russia is actively developing breakthrough reactor and closed nuclear fuel cycle technologies for resolving key issues hindering nuclear power.

This new technological platform (NTP) is envisioned to become the main source of carbon-free energy for the country's future energy mix.

A nuclear energy system based on NTP solutions will exhibit the following features:

- «Inherent» safety of reactor technologies;
- An unlimited resource base (based on U238 instead of U235);
- A solution for SNF accumulation using the radiologically-equivalent approach to nuclear waste disposal;
- Technological nonproliferation support;
- Economic competitiveness of nuclear power plants.

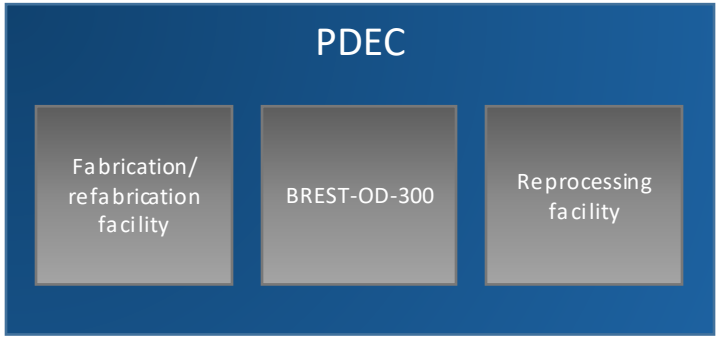


Without resolving the issue of SNF or MA, nuclear power cannot truly be considered «green». Innovative technologies must address the need to eliminate the source of potential biological hazard arising from nuclear waste at time scales accepted by society.

Pilot demonstration energy complex (PDEC)

Demonstrating the feasibility of an «inherently» safe nuclear reactor with a closed nuclear fuel cycle

1. PDEC is comprised of three key elements – the reactor BREST-OD-300, fuel fabrication/refabrication facility and the reprocessing facility
2. Mixed nitride U-Pu fuel is envisioned as standard fuel for all lead-cooled reactors
3. The objective is to justify the feasibility of closed nuclear fuel cycle components before transitioning to large-scale nuclear power reactors
4. PDEC will feature state-of-the-art «on-site» fuel fabrication and repressing capabilities. All fuel operations will be performed on site – with no need for long-distance transport of fuel or SNF
5. Prove that MA from thermal reactor SNF can be successfully burned
6. PDEC is a power generating complex, producing electricity as well as R&D assets



«First concrete» ceremony at PDEC site (June 2021)

Current progress on closed nuclear fuel cycle technology development

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Fuel

Technology and installation/equipment development for manufacturing mixed nitride fuel for fast reactors

- Technology for manufacturing mixed nitride fuel from SNF energy materials developed;
- Experimental fuel fabrication facility created;
- Mixed nitride fuel refabrication technology with MA for closed fuel cycle application experimentally developed;
- Fuel fabrication module to be commissioned in 2024

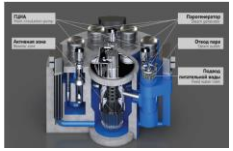
Fuel element assemblies

Experimental mixed nitride fuel element and assembly development

- MN fuel element for BREST-OD-300 startup core certified;
- Fuel performance up to 9 at % burnup (damage dose ~110 dpa) experimentally confirmed in BN-600;
- Fuel codes updated (BERKUT, DRAKON, KORAT)
- Digital models for fuel performance simulation developed

BREST-OD-300

Demonstration lead-cooled reactor

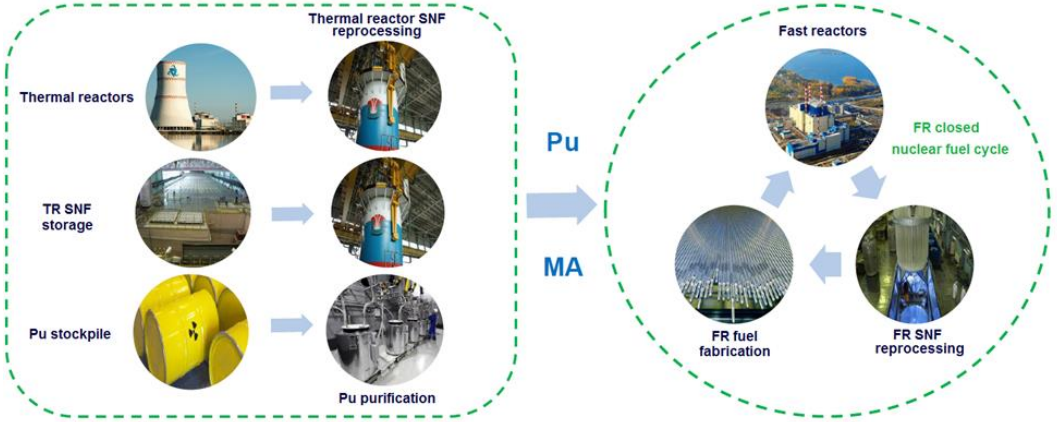


- BREST-OD-300 design project and documentation developed;
- Reactor construction license acquired and construction initiated SCC (Siberian Chemical Combine) site
- Technical proposal completed for BR-1200 lead-cooled nuclear reactor rated at 1250 MWe installed capacity as an extension of the BREST reactor family

FR nuclear fuel cycle

An optimal FR NFC from a NTP perspective should imply:

1. Pu together with MA is recycled in the FR; recycling U-Pu in thermal reactors complicates and worsens the cycle for the whole system.
2. All MA from reprocessing thermal reactor SNF are burned in FRs. **MA are not included in vitrified HLW package destined to disposal**.
3. Fuel consumption is balanced so that no breeding blankets resulting in high breeding ratios are needed;
4. Fuel regeneration and MA transmutation are concentrated in the reactor core.

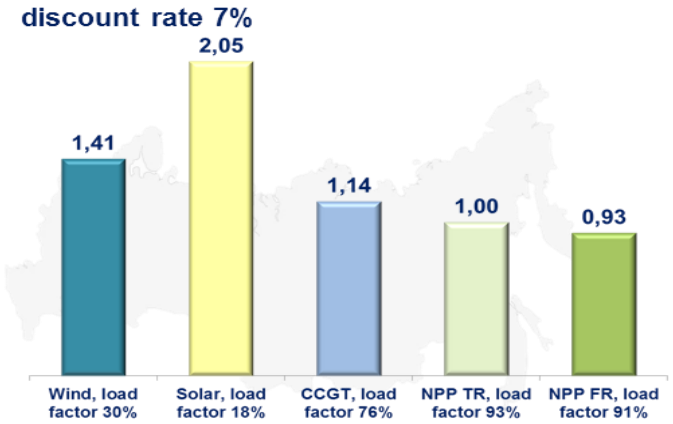


Minimizing the wastes from SNF is a priority for closed NFC energy systems

Competitiveness of project «Proryv» technologies

LCOE energy technologies in Russia (forecast for 2035-2040), relative units

Parameter for FR-1200	Requirement
Unit capacity, MW(e)	~1250
Cr, %	93
Normal-mode ratio., pers./MW(e)	0,3
Service power, %	5,0



- The FR-1200 should be competitive compared with alternative generation in terms of LCOE
- The requirements set ensure the competitiveness of an Industrial Energy Complex (combines power plant with on-site NFC facilities) taking into account current forecasts of innovative development of alternative generation technologies

the calculations LCOE are carried out on the basis of the relevant methodology guidelines of the State Corporation “Rosatom”

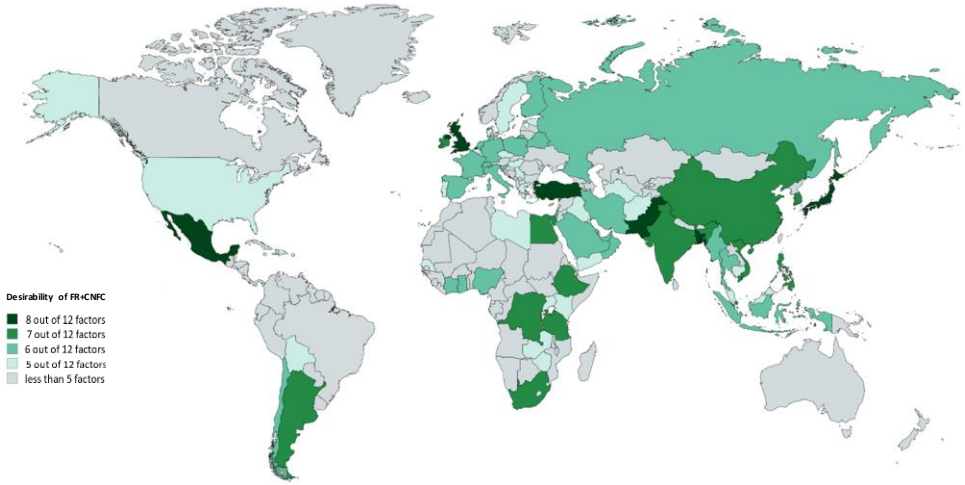
International cooperation within the framework of a global technological platform for fast reactor and closed nuclear fuel cycle technology development

There is a clear need for technologies that could deliver low carbon energy at scale;

The dependence on fossil fuels can be mitigated using safe, reliable nuclear power;

Energy prices are highly volatile, and will remain so if alternative solutions are not found in the coming decades;

Russia is not part of the problem, it is part of the solution.



Map developed based on multi-criteria analysis on identifying countries where FRs and CNFC technology is most desirable for sustainable development*

A global push towards fast reactor and NFC technology development will jump-start the next green energy revolution

* From Proryv studies on FR and CNFC global potential

MISSION of cooperation based on PDEC

- Creation of an international technological platform for the construction of a two-component nuclear power system based on innovative technologies FR and CNFC
- Formation of the energy generation market for environmentally friendly and radiation-safe nuclear energy
- Formation of the nuclear generation market based on innovative technologies

*Industrial power complex

The goals of international cooperation based on PDEC and IPC*

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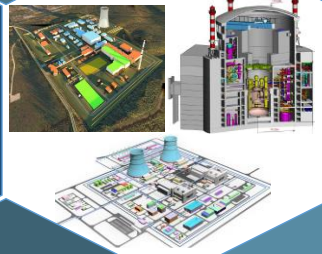
Real international education for young engineers

Creation of the world center of technological competencies for FR and CNFC

Ensuring the distribution and development of FR and CNFC technologies

Formation of broad cooperation by combining the resources of different countries



Development of an experimental technological base for the industrial implementation of international projects

New international norms and rules of the Nuclear Power Plant

Cultivating nuclear innovation best practices and engineering culture

Market formation and confirmation of the feasibility of two-component nuclear power

Using the FR platform for generating new ideas and cooperation between countries

FR and NFC technology development could benefit from international cooperation. The FR conference could act as a platform for generating new alliances in the field of next generation nuclear power technology.

Different approaches and strategies to closing the nuclear fuel cycle can be discussed, analyzed and peer-reviewed for practical implementation for advanced nuclear or new-comer countries.

Russia is committed to raising awareness on the significance of FRs and closed NFC technologies. There is a real chance of establishing energy security on a global scale.