ROSATOM

STATE ATOMIC ENERGY CORPORATION “ROSATOM”

NUCLEAR R&D ACTIVITIES IN RUSSIA

L. ANDREEVA-ANDRIEVSKAYA

State Atomic Energy Corporation «Rosatom» (ROSATOM)
Russian Federation

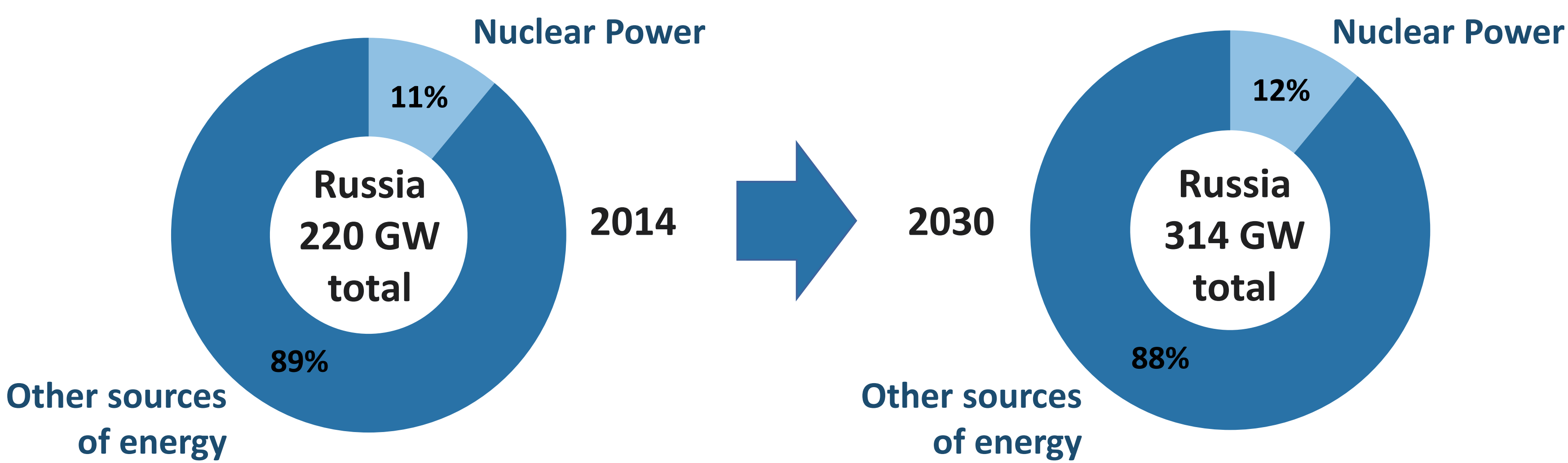
NI2050 Workshop
July 2015, Paris

Contents List

Nuclear Power in Russia: Status and Prospects

Present NP in Russia is based on thermal reactors (VVER - 17/ RBMK - 11) and open nuclear fuel cycle technologies.
Just one sodium fast reactor BN-600 in operation and new BN-800 starts operating in 2015

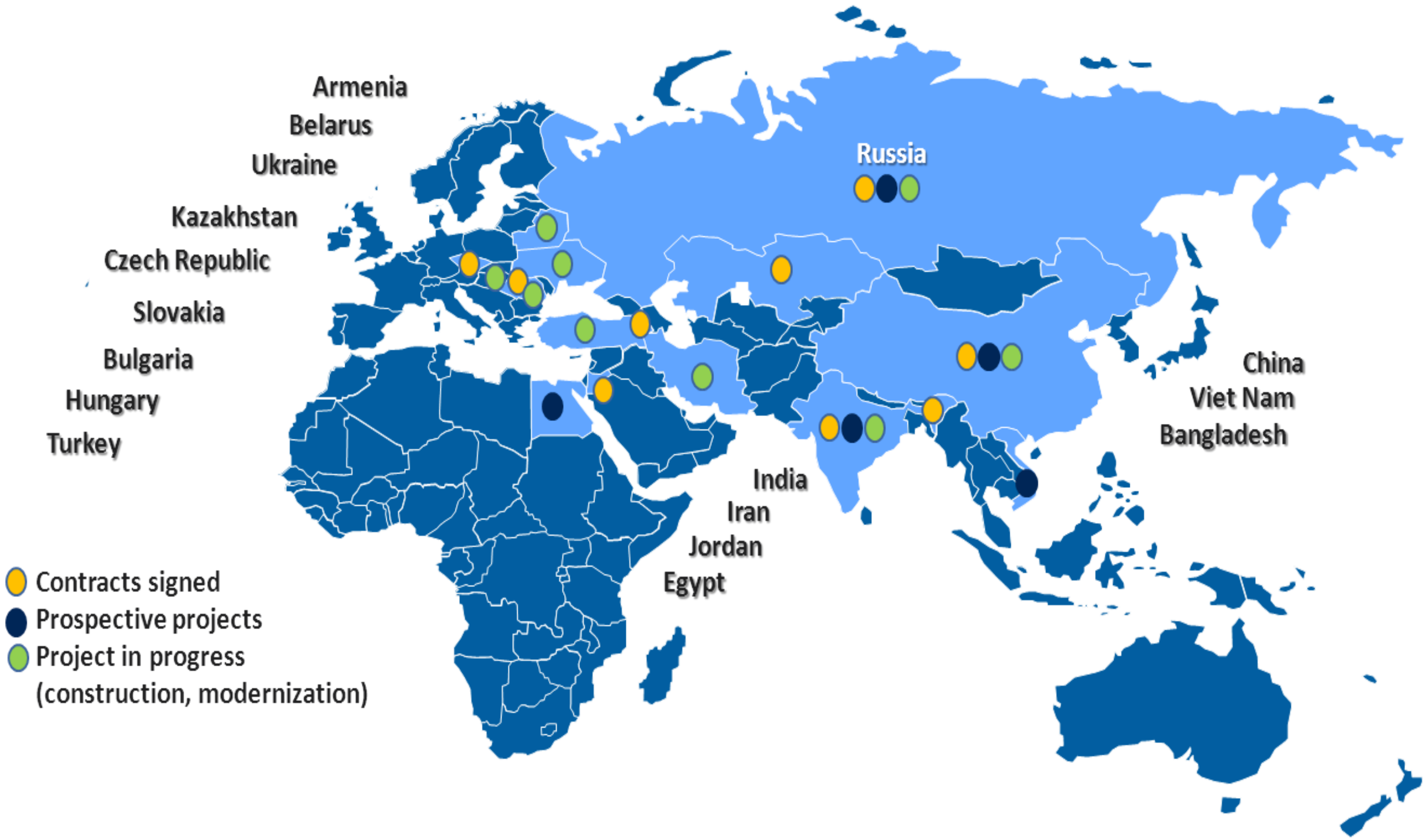
"Energy Strategy of Russia" consider scenarios of 18 new NP reactors construction with 21 GW capacity (overall increase - 14 GW assuming shutdown of old NPPs) by 2030



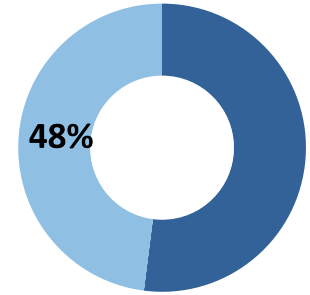
NP share in electricity generation is 17 %

NP share in electricity generation is 20 %

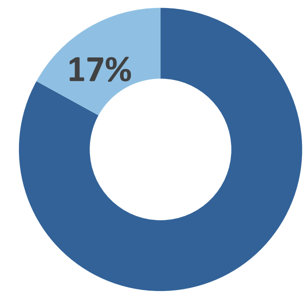
Russia in Global Nuclear Industry



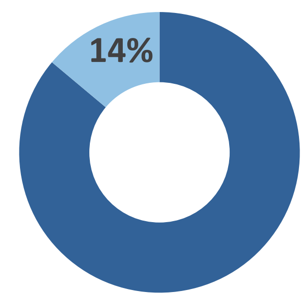
Uranium enrichment



Nuclear fuel



Uranium production



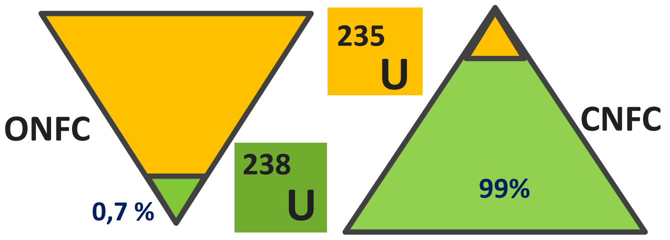
29 new reactors (+ 9 under discussion) around the world by 2030

Russian Strategy
of the Large-Scale Nuclear Power Development

РОСАТОМ

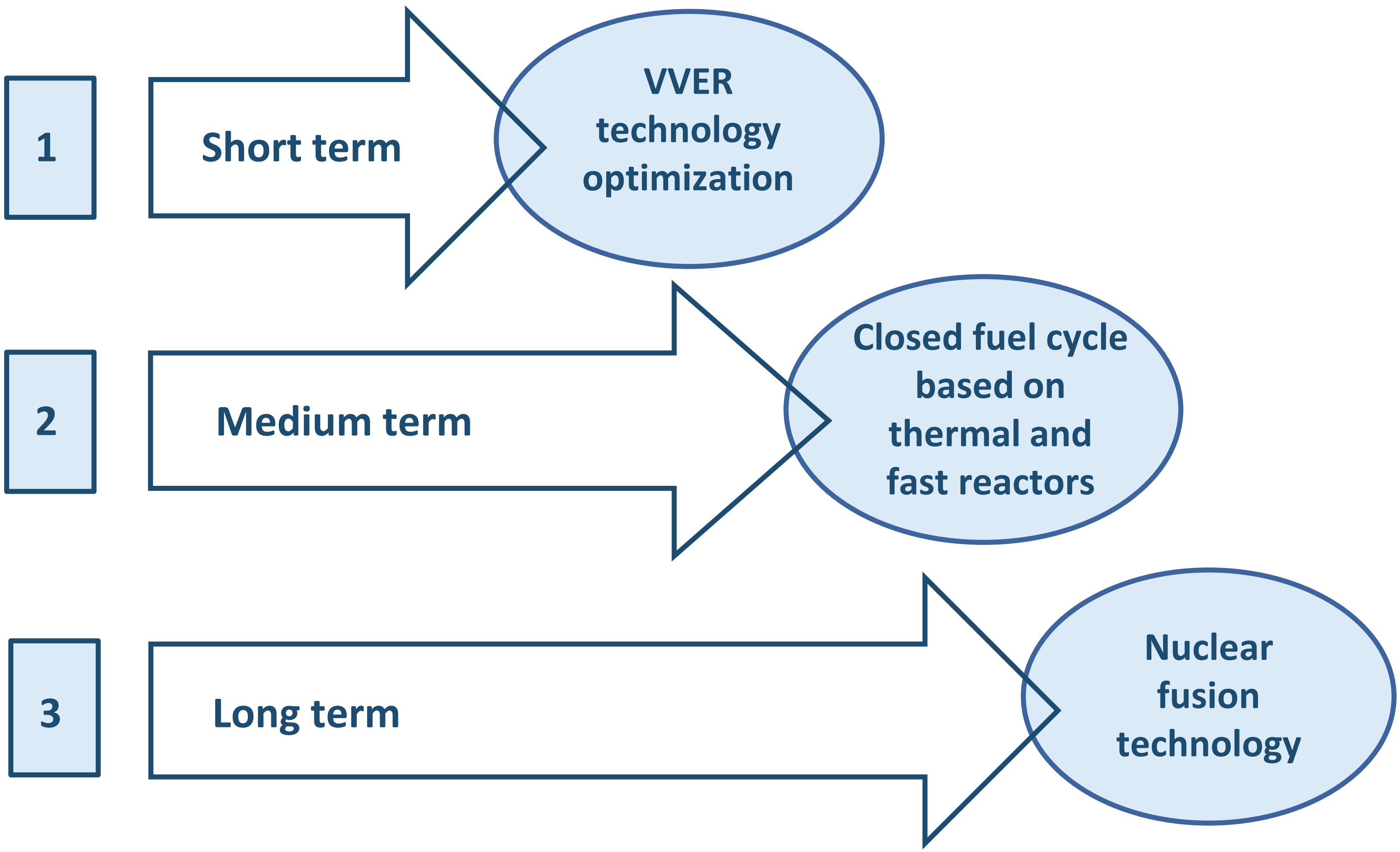
Criteria for the development of large-scale nuclear power with "inherent" safety

1. Exclusion of the accidents which require evacuation or relocation of local population (breeding ratio BR = 1,05)
2. Efficient use of natural U energy potential
3. Multi-reprocessing of nuclear materials in a way preserving the natural radiation balance (equilibrium mode in 25 years)
4. Minimization of high-level wastes through multi-reprocessing of MA with U-Pu mix (decrease of radioactive waste 5 times)
5. Technological reinforcement of the non-proliferation regime (not separation of Pu & Ur)
6. Competitiveness of nuclear power
   LCOE (ONFC+GAS PP)>LCOE (CNFC)



The above mentioned requirements can be met only by integrated development of new generation FR and CNFC technologies

ROSATOM Programme of Innovative Development and Technological Modernization



R&D: Structure

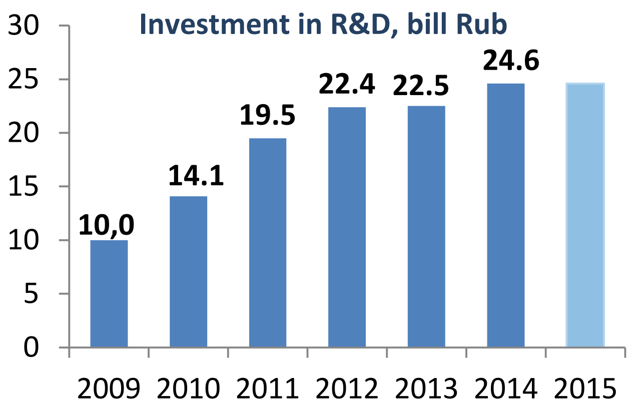
R&D areas based on Nuclear Fuel Cycle

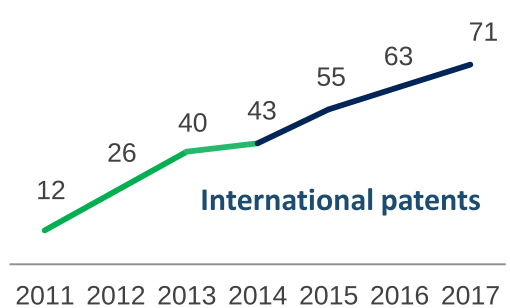
- Uranium mining
- Uranium conversion
- Uranium enrichment
- NF fabrication and re-fabrication
- Electricity and heat generation
- Treatment and recycling of SNF
- RW treatment

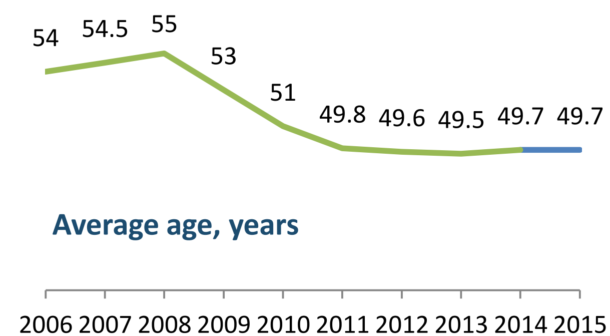
R&D areas based on the NP Life-Cycle

- Designing and Constructing
- Equipping and Building
- Operation
- Maintenance and Resource Extension
- Decommissioning

Statistics for the last 5 years







R&D: Needs and Infrastructure

R&D: Strategic Needs

- Increasing of nuclear fuel cycle duration
- Development of robust fuel for present LWR fleet
- Licensing majority of the commercial PWRs for the 60 years
- Minor actinide transmutation
- Proliferation resistance fuel
- Fuel & reactor materials for next generation reactors (VHTR, SFR, GFR, LFR, Supercritical WR, MSR) are to be tested and approved

R&D: New Generation Infrastructure

- High flux reactor
- Experimental loops with different types of coolant
- Instrumented reactor cells for in-pile testing
- PIE hot cells
- Research labs
- Facilities for manufacturing of samples, test devices, assemblies, etc.
- On-site fuel fabrication and spent fuel handling facilities
- Development of new codes
- Development of supercomputer technologies
- Highly qualified staff
- Developed social infrastructure and acceptable transportation availability

R&D: Areas

РОСАТОМ

Life Cycle Stage	R&D Area
Uranium Mining and Conversion	Technology of integrated geological modeling
Nuclear Fuel Fabrication and Re-fabrication	New fuel compositions and fuel rods (MOX and remix fuel for LWRs, dense FR fuel, fuel with MA)
	Large-scale involvement of reprocessed uranium in the NFC
	New structural materials for fuel rods and FA development
Electricity and Heat Generation	Development of power generating units with FR
	New source of fusion energy development and implementation
Treatment and Recycling of Spent Nuclear Fuel	Creating pyro-, electro-chemical and new hydrometallurgical technologies for SNF recycling
	Development of technologies of minor actinides fractionation and recycling
	Development of the basic technology for thermal reactors SNF processing at Pilot Centre (JSC “Siberian Chemical Combine”)
RW Treatment	R&D in long-term safety of RW deep dumping
Nuclear, Radiation and Environmental Safety	Information and simulation modeling of territories and objects for the main types of radiation-dangerous works
	Numerical and experimental methods of nuclear, radiation and ecological safety analysis and substantiation
Life Cycle Digital Technologies	Development of new codes for design, technological and engineering solutions at the stages of the life cycle of nuclear facilities substantiation
Nuclide, Laser, Plasma and Radiation Technology	Properties in accident conditions
Isotopes	New methods of isotope separation and enrichment research and application

Management of ROSATOM Scientific Organizations: JSC «Science and Innovations»

Physics and Power Bloc	Electro-physical Bloc	Chemistry and Technology Bloc
□ R&D in the area of reactor, radiation and nuclear technologies □ Research nuclear reactors and experimental installations □ Works in the area of fast neutron reactors (BN-600, BN, BN, BREST, SVBR-100) □ Developing new power systems □ Developing and manufacture of fuel, structural, and absorbing (based on Boron-10 and rare-earth metals) materials □ Isotopes and RPh □ Developing innovative non-nuclear technologies	□ Plasma and laser technologies; □ Radiation technologies □ Nuclear medicine (tomographs, cyclotrons, accelerators, gamma-ray plants) □ High-temperature superconductors: materials and equipment on their basis □ Non-destructive testing technologies □ Inspection systems	□ New materials based on rare-earth metals; Technologies of uranium, rare-metal and other ores processing □ Obtaining nuclear-clean structural materials, high-purity substances, semiconductor materials □ Interaction of nuclear ionizing irradiations with substances and materials □ Developing radiochemical, radiation-chemical, nuclear-physical technologies of manufacturing products,functional materials, nano-materials and nano-technologies

Federal Target Program
"Nuclear Power Technologies of a New Generation"

The following major facilities are planned to be developed and commissioned by 2020:

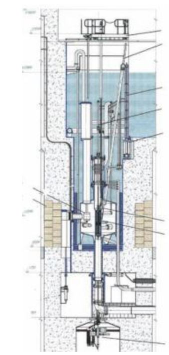
- MOX fuel production line for BN-800 reactor – 400 nuclear fuel assembles per year since 2015 (accomplished), remix fuel for LWRs
- Nitride fuel technology is completed:
  6 fuel assembles have been loaded in BN-600.
  Nitride fuel production plant – 14 tons/year
  (2014 - start of construction)
- Multi-purpose fast research reactor MBIR *(2015 – start of construction)*, PIK *(2019 – target)*
- Prototype power unit with lead-cooled fast reactor BREST-300 (2016 - start of construction)

  300 MW (700 MW thermal) gives assurance of a minimal reactivity margin in the reactor core, by achieving core BR =1.05
- Design and construction of the on-site closed fuel cycle facilities for BREST-OD-300
  (final proof for close fuel cycle technologies by 2025)

MOX-fuel

MBIR

PIK



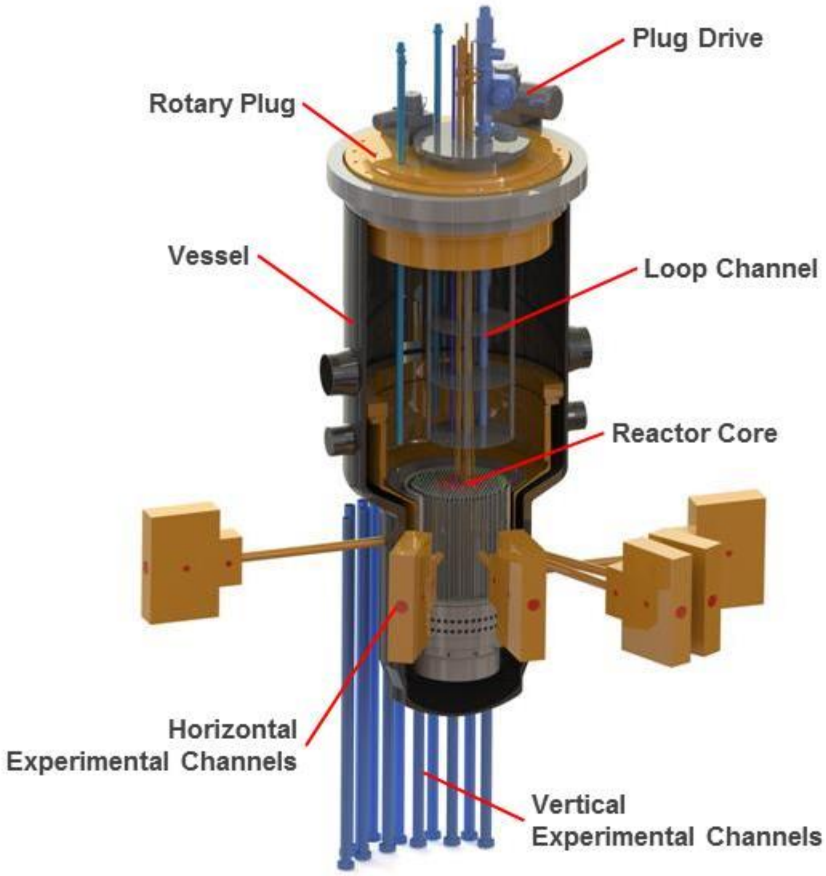
BREST

MBIR: Unique Research Facility

ROSATOM

MBIR is a Multipurpose Sodium Fast Research Reactor

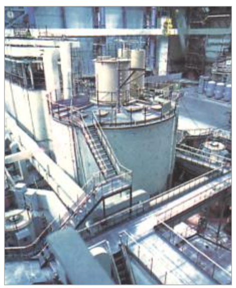
- Heat power: 150 MW(t)
- Maximum fast neutron flux: $5.3 \cdot 10^{15}$ n/(cm^2·s)
- Coolant: Pb, Pb-Bi, Na, He, salt
- Ten horizontal and vertical channels
- Upgradeable experimental capabilities (more loops, irradiation devices, channels, neutron beams, etc.),
- PIE facilities & analytical labs
- Testing of materials for Generation-IV innovative nuclear reactors (there are 3 loop channels in the core with irradiation parameters under control)
- Commissioning in 2020 (target)
- Designed life time: 50 years



Development of Metal Cooled Fast Reactor Technologies

Total reactor-years ~ 140

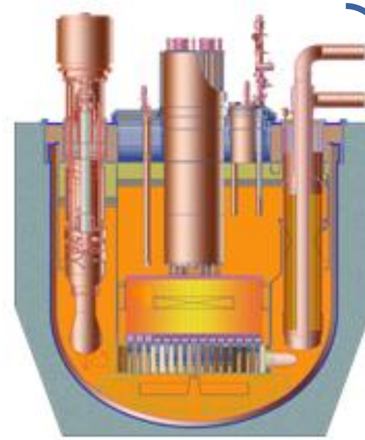
BN-350 (1973)



BN-600 1980)

BN-800 (2015)

BN-1200 (2025)

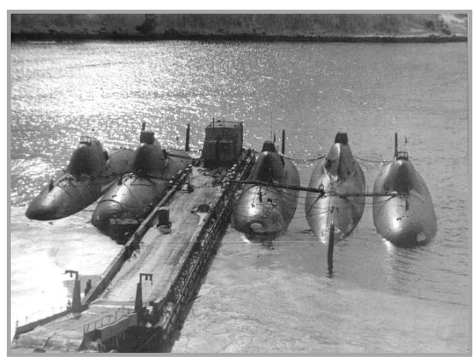


Na

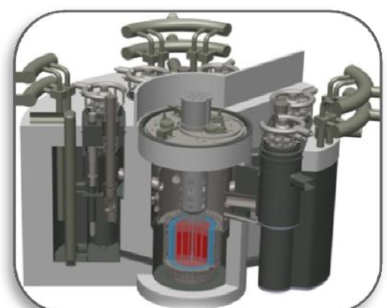
Pb-Bi

Experimental facility (1951)

APL-705 experimental (1971)



APL-705 serial (1976-1996)



BREST-300 (2020)

Commercial solution for fast reactor with CNFC

FR-1200

“Proryv” Project

РОСАТОМ

“Proryv” Project (“*Breakthrough*”)

“Proryv” Project, which is to develop new generation nuclear power technologies,
based on the closed nuclear fuel cycle with fast neutron reactors,
has been implemented under the FTP “Nuclear Power Technologies of the New Generation for the period of 2010–2015 and until 2020” (FTP NPNG).

“Proryv” Project is the transition from a demonstration of separate innovative technologies to the integrated world-class solution, i.e. a pilot demonstration facility that includes the on-site nuclear fuel cycle.

The project involves 30 organizations, of which 19 are scientific and educational entities, and the total number of engaged scientists exceeds 1,500.

"Proryv" Project Approache to Global NP Sustainability. Similarities with INPRO Basic Principles

POCATOM

1. Sustainable global nuclear energy system requires improvement of current nuclear power characteristics in key areas: safety, security, non-proliferation, waste, resource sustainability and economy
2. A system based on fast reactor and closed fuel cycle technologies will be a critical component of any large scale sustainable global NP
3. Development of FR and CNFC technologies is challenging and important mission, particular for nuclear technology developer countries using or aiming to use nuclear energy at large scale level
4. Cooperation and assistance of nuclear technology holder countries to technology user countries, particularly in such areas as infrastructure, nuclear safety, security of fuel supply, waste management, and assurance of non-proliferation
5. Transition from present NP system to the future FR based one will be achieved via 2-component (VVER+FR) intermediate NP system
6. External fuel sources: Pu in stock existing + Pu to be produced by LWRs + uranium fuel

R&D: Radiation Study of Materials

РОСАТОМ

Reactor and experimental installation complex

Material study complex

- Research in the area of the reactor material technologies
- Improvement of structures
- Justification of the structures' operability
- Research of the material initial physical and chemical properties
- Research of the products after irradiation in NPP
- Research of radiation properties of the materials and products
- Developing and manufacture of experimental materials and products
- Testing the product mockups at specialized test facilities

Reactor Core Materials Study: Experimental Base

РОСАТОМ

Russian research infrastructure includes

- **6 Research Reactors**
  BOR-60, SM-3, MIR, RBT-6, IVV-2M, BARS-6

- **6 Critical Facilities (*zero power reactors*)**
  including BFS-2 - the largest operating critical test facility in the world

- **5 High-voltage Accelerators**
  with the energies of singly charged ions within the range of 0.3-15 MeV (Tandertron - 2016)

- **More 70 Test Facilities**
  for the fundamental research of the development of theory and computer codes

- **More 80 Hot Cells of Testing Complex**
  in RIAR-the largest in the world

Reactor BOR-60 in RIAR

Lead-Cooled Experimental Facility (IPPE)

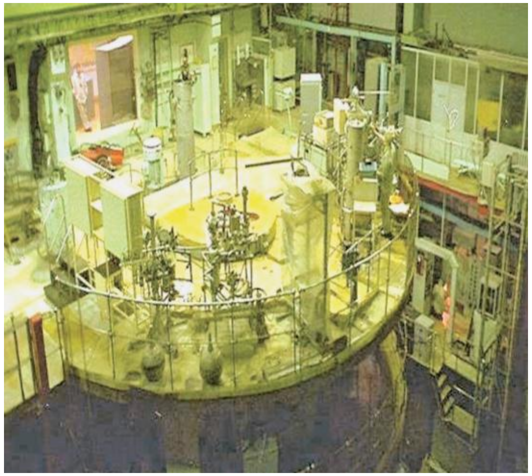
Hot Cells in RIAR

Experimental Base: Research Reactors

All research reactors are successfully operated and no failures were registered for the last 10 years.
The last modernization of the SM reactor was completed in 1993 and it can be operated till, at least, 2050.

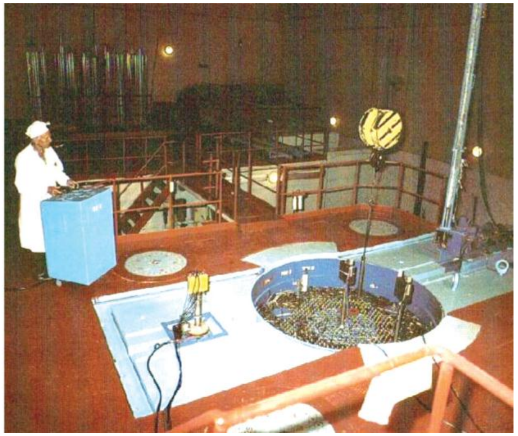
Reactor BOR-60 in RIAR

Reactor MIR M1 in RIAR



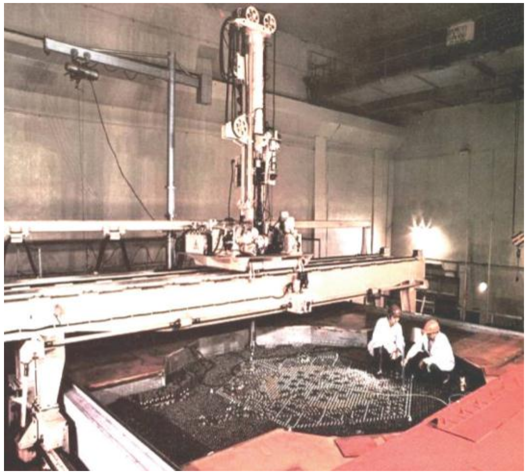
Reactor IVV-2M in IRM

Experimental Base: Critical Assemblies



BFS-1

Russian Federation owns two unique Critical Assemblies (IPPE): BFS-1 and BFS-2) for investigating the fast reactors neutron-physical parameters



BFS-2

Critical facility ASTRA (NRC KI) is used for the research of neutronic characteristics of different HTGR core configurations, acquisition of experimental data for validation of calculational models and codes

ASTRA

Experimental Base: Facilities for Thermo-Physical and Thermo-Hydraulic Research

РОСАТОМ

Thermo-physical facilities provide a good opportunity for investigation of all available coolants, especially the metal ones, for innovative NPP projects.

Many facilities for research
of thermo-physical parameters
of different coolants for innovative reactors
are concentrated in IPPE, EREC, OKBM, NIKIET

NIKIET:
Water High Pressure Stand SVD-2 Large Hydraulic Test Bench (LHTB)

NIKIET:
Supercritical Parameter Bench (SCPB)

OKBM (He):
High-Temperature Gas Facility

EREC (H2O):
PSB-VVER Test Facility

IPPE (Pb):
TT-1M Facility

Fundamental Research for Nuclear Energy: Examples

POCATOM

Research of properties in accident conditions

- Hydrogen stratification in severe accidents
- Powerful pulse-periodic neutron source basing on plasma accelerators
- Thermal, mechanical and kinetic properties of materials at high energy densities
- Dynamic compressibility and electro-physical properties in extreme conditions

Development of technologies for direct conversion of nuclear energy

- Creating physical foundations of photovoltaic batteries-dust plasma
- Prototype of nuclear energy optical converter with nuclear reactor pulse pumping
- Development of electrical thermo-emission batteries based with 20-25% efficiency.

Development of new generation of ionizing radiation detectors

- X-ray and Gamma-radiation detectors basing on CdTe and CdZnTe
- Solid scintillation antineutrino detector nuclear reactor parameters monitoring
- Electronics and support systems for cosmic radiation muon-tomograph

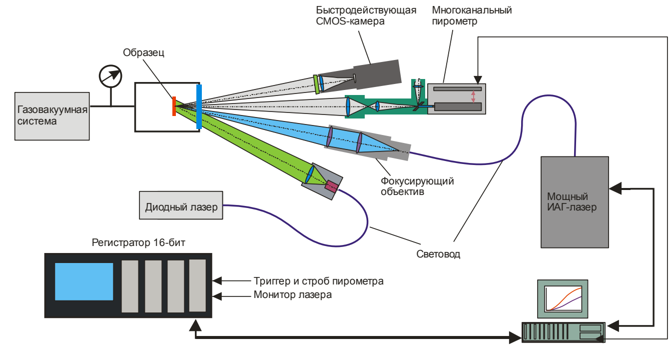
Fusion research and development of material surface strengthening technologies based on the laser, beam and plasma

- T-10 tokamak experiments
- TIN engineering design with DT power exceeding 10 Mw
- Research and simulation of plasma-surface interaction processes in tokamak
- Tungsten-lithium limiters prototypes development and testing in T-11

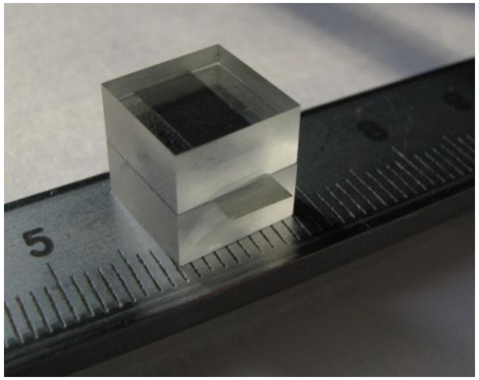
Fundamental Research for Nuclear Energy: Examples (TRINITI)

РОСАТОМ

Data Bases "Thermophysical, Strength and other Properties of Materials at High Energy Density"



- Thermophysical properties of zirconium carbide which is a promising inert matrix for high temperature nuclear fuels (UC-ZrC, UC-ZrC-NbC-TaC, UN-ZrN etc.)
- Composition of incongruent evaporating super-stoichiometric uranium dioxide vapor and stoichiometric zirconium carbide at up to 4100 K temperatures
- Hafnium electrical conductivity and specific internal energy from normal density to 6 times lower ones and at 1-8 GPa pressure
- Titanium, zirconium and alloys, reactor steels, ceramics and glass strength characteristics, at deformation speed of 103-107 s^{-1} (up to 109 s^{-1}) at up to 700 °C temperatures
- Radiation resistance, and radiation damage accumulation kinetics in UN-ZrC, UN-ZrN, ZrO_2-UO_2, U-ZrO_2, Zr-UO_2



R&D Infrastructure:
Development of Supercomputer Technologies

POCATOM

LOGOS (LOGOS-CFD, LOGOS-Strength), DANKO+Gepard, NIMFA developed under the project "Development of Supercomputers and Grid Technologies" (2010–2012)

Supercomputer codes are intended for modelling of a broad range of physical processes (gas, aero, hydro dynamics, acoustics, heat and mass transfer, turbulent mixing, strength, deformation and destruction, multi-phase multi-component filtration, etc.).

More than 200 state-of-the-art physical and mathematical models, numerical methods and algorithms are developed.

New series specimen of the universal small-size supercomputer APK-1M2, based on cutting-edge engineering solutions, was developed and successfully passed tests.

Results of Implementation of ROSATOM Programme of Innovative Development and Technological Modernization

Programme Implementation Indicators	2011	2012	2013	2014
R&D financing (% of proceeds)	4.0	4.78	4.53	4,5
Number of patents in foreign states (European Union countries, U.S., Japan, etc.) granted for results in research and development, know-how and results of intellectual activities (progressive total) (number/year)	12	26	40	57
Number of registered know-how for results of intellectual activities in science and technology (number/year)	65	71	81	83
Proceeds per person (as calculated per employees of research institutes) (RUB thousands/year)	921	1222	1244	1351
Percentage share of financing of R&D orders placed with universities of the total R&D financing	4.5	3.52	4.1	4,5
Percentage of R&D carried out by entities outside the nuclear sector	13.8	15.7	17.2	14,2

Thank you
for your attention!