ROSATOM STATE ATOMIC ENERGY CORPORATION

International Cooperation for Development of Innovative Energy Technologies

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Rosatom State Corporation Scientific Division

ROSATOM

SCIENCE AND INNOVATION
Innovation Management Company

Innovation Management Company "Science and Innovation" was established in 2011 to control the assets and R&D activities of Rosatom research institutes

We possess **the whole range of competences necessary to provide scientific services** in the following fields: energy and non-energy nuclear technologies, construction and functional materials, extraction and processing of raw materials, radiation application and survey technologies

Research and Development	Scientific Services and High-tech Manufacturing	Developing Comprehensive Scientific Programs for Customers	Developing Scientific Infrastructure for Customers	Training for Scientific Personnel

Department of Energy Physics

НИИАР · НИИ НПО "ЛУЧ" · ГНЦ РФ - ФЭИ · ИРМ

Department of Chemistry and Technology

НИИГРАФИТ · ВНИИХТ · ГИРЕДМЕТ

Department of Electricity Physics

ТРИНИТИ · НИИЭФА · НТЦ ЯФИ

11 scientific research institutes, including:

- 3 public science centers (RIAR, IPPE, TRINITI)

9.5 thousand employees, including:

- 1936 researchers
- 154 Doctors of Sciences
- 557 Candidates of Sciences
- 77 postgraduates

182 experimental research facilities, including:

- several unique facilities for reactor material science, plasma research and laser technologies

Competences of Scientific Division

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Experimental Facilities

- majority of the operating Russian research reactors
- more than 60 shielded chambers and hot cells
- unique heavy-duty (high-flux) SM-3 reactor
- unique BOR-60 fast research reactor
- a large core physics simulator and etc.

Isotopes

Mo-99,	Cf-252,	Ir-192,
Sr-89,	Co-60,	Se-75,
Lu-177,	Ac-225,	Pu-238,
Cs-131,	I-131,	I-125,

- Generators Re-188 and etc.

Lasers and Plasma

- Plasma single-pulse processing of complex shape parts
- Mobile laser technology complexes (MLTC)
- Lithium limiter of longitudinal and transverse type for Tokamak T-15, etc.

SCIENCE AND INNOVATION
Innovation Management Company

Structural and Functional Materials

- Graphitized fabric
- Fullerenes: nano-materials used in polyurethane, caprolon, polyurethane foam
- Fine-grained, antifriction, isostatic graphite
- Endoprostheses

Sensors, Devices and Equipment

- Equipment for NPP
- Sensors for various measurements
- Devices for control, safety and security

Complex Processing of Ores, REM, Uranium-containing Materials

- Concentration
- Hydro- and pyrometallurgy
- Pyrometallurgy

International Projects of the Scientific Division

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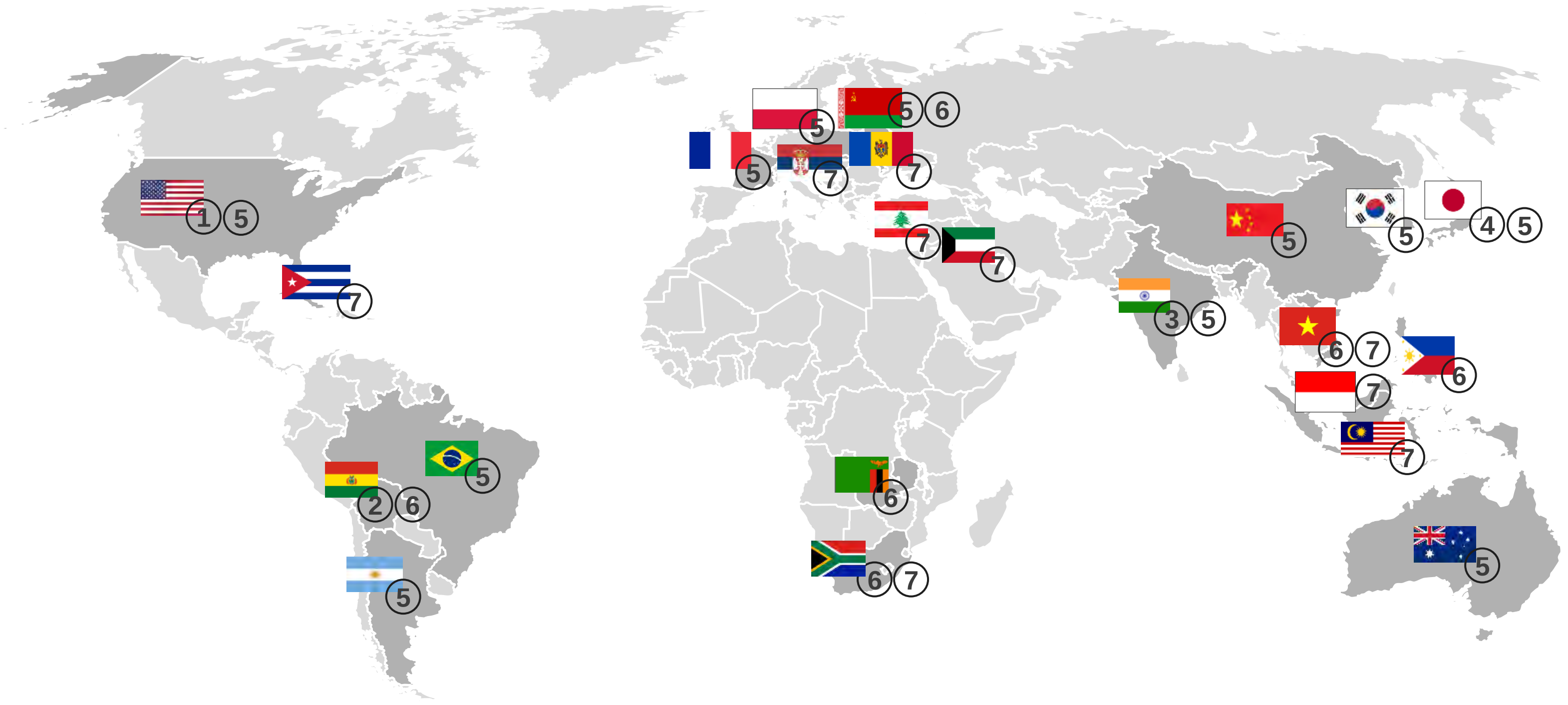

1 USA
JSC "IRM" supplies Ir-192 to the largest consumer of this isotope in the world - QSA Global Inc. (USA)

2 Bolivia
Transport radiation monitors and radiation safety system by JSC "Scientific and Technical Center "Yafi“ were installed at the El Alto airport

3 India
Sources of radiation based on curium-244 produced by SSC SRIAR JSC were delivered to the Laboratory of Physical Investigations

4 Japan
JSC IPPE developed a neutron detector for the study of the Fukushima NPP

5 Australia, Argentina, Belarus, Brazil, India, China, Poland, United States, France, Republic of Korea, Japan
Supply of isotope products is carried out by JSC Isotope

6 Belarus, Bolivia, Vietnam, the Philippines, South Africa, Zambia
Bolivia is creating a Center for Nuclear Science and Technology (CNST), other countries are considering a CNST

7 Vietnam, Indonesia, Cuba, Kuwait, Lebanon, Malaysia, Moldova, Serbia, South Africa
Radiation portal monitors and united safety radiation system were developed by JSC "Scientific and Technical Center" Yafi“ jointly with the IAEA

International Cooperation: Key Facts 2018

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Commercial cooperation

- R&D services
- Innovative production
- Isotopes
- CNST
- Lasers and plasma

Non-commercial cooperation

- Scientific and technical cooperation
- IAEA conferences
- Technical tours
- Exchange programs

30
countries

56
products and services

188
international events

58
receptions of foreign delegations

$48M
2018 revenue

$111M
2018 portfolio of orders

$400M
2019 potential portfolio of orders

Two-component Atomic Energy - a Synergistic Coexistence of a Reactor park on Thermal and Fast Neutrons

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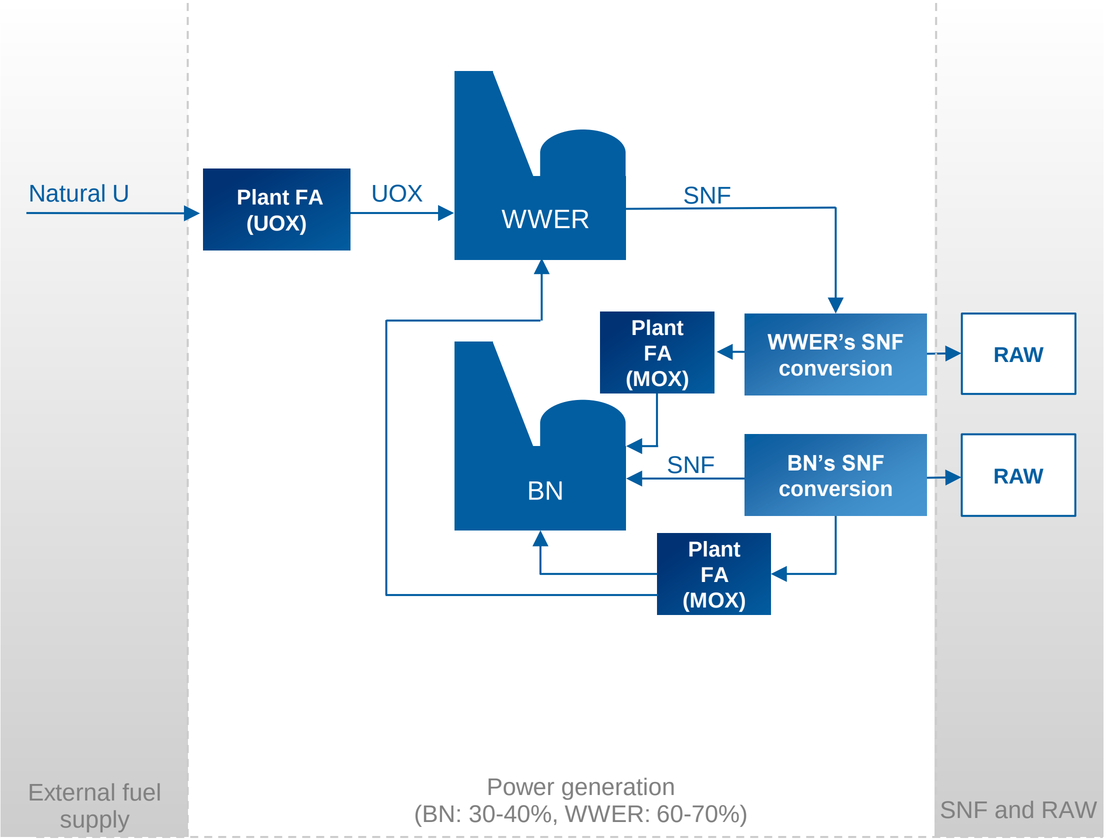
Reactors on thermal neutrons

+

Reactors on fast neutrons

- Solving the problem of SNF accumulation in the world
- x10 increase in efficiency of using raw uranium
- Minimize the waste with a half-life reduction due to minor actinides transmutation in fast neutron reactors

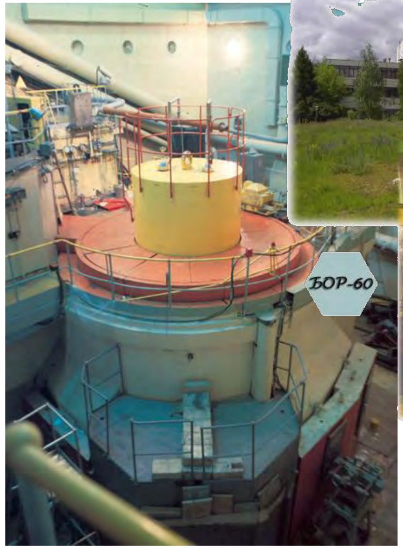


Two-component atomic energy is also based on a cheaper WWER technology

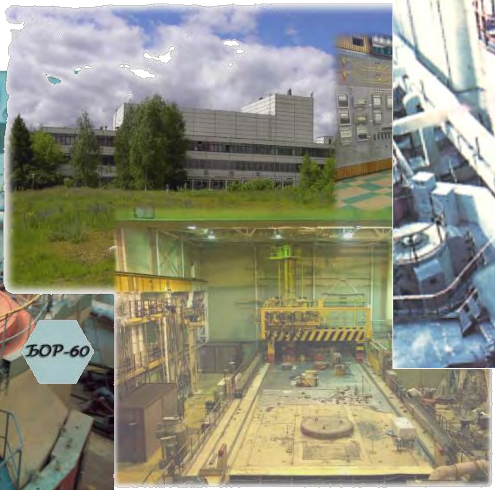
Recycling of nuclear fuel requires effective solutions to improve SNF reprocessing technologies and to include minor actinides in the fuel composition

Sodium Fast Reactor Development Stages in Russia

Rosatom Scientific Division is the Scientific Leader of the Russian Sodium Fast Reactors

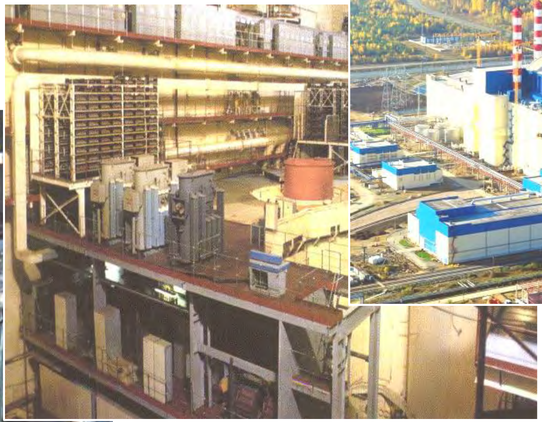


BR-5/10 (1959)



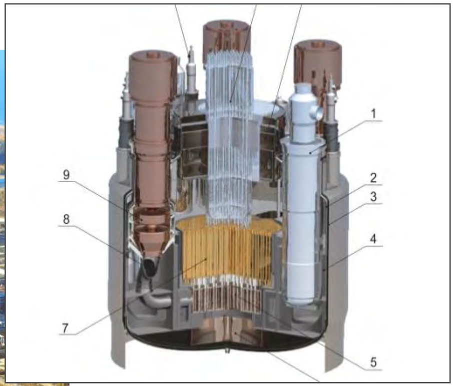
BOR-60 (1969)

BN-350 (1973)



BN-600 (1980)

BN-800 (2015)



BN-1200 (2027)

- The main peculiarity of the Fast Reactors is that ^{238}U and ^{232}Th could be involved into the Nuclear Fuel Cycle. Natural reserves of the ^{238}U and ^{232}Th are much bigger than ^{235}U, which now is the main fuel for the Thermal Neutron Reactors.
- Fast Reactors could solve the Spent Nuclear Fuel issue of the currently existing Thermal Neutron Reactors.
- These features have the most value in Closing of the Nuclear Fuel Cycle

Fast Neutron Critical Facilities and Research Reactors

Rosatom Scientific Division is the Scientific Leader of the Russian Sodium Fast Reactors

IPPE (Obninsk):

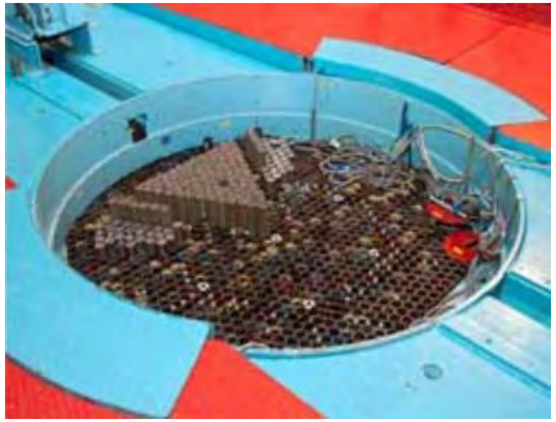
- BR-1 (1955)
- BR-2 (1956)
- BR-5 (1959)
- BR-10 (1973)
- BFS-1 (1961)
- BFS-2 (1970)

RIAR (Dimitrovgrad):

- BOR-60 (1969)
- MBIR (to be commissioned in 2025)

BR-1 – the First European Fast Neutron Research Reactor

BFS-2 – The World Biggest Experimental Facility



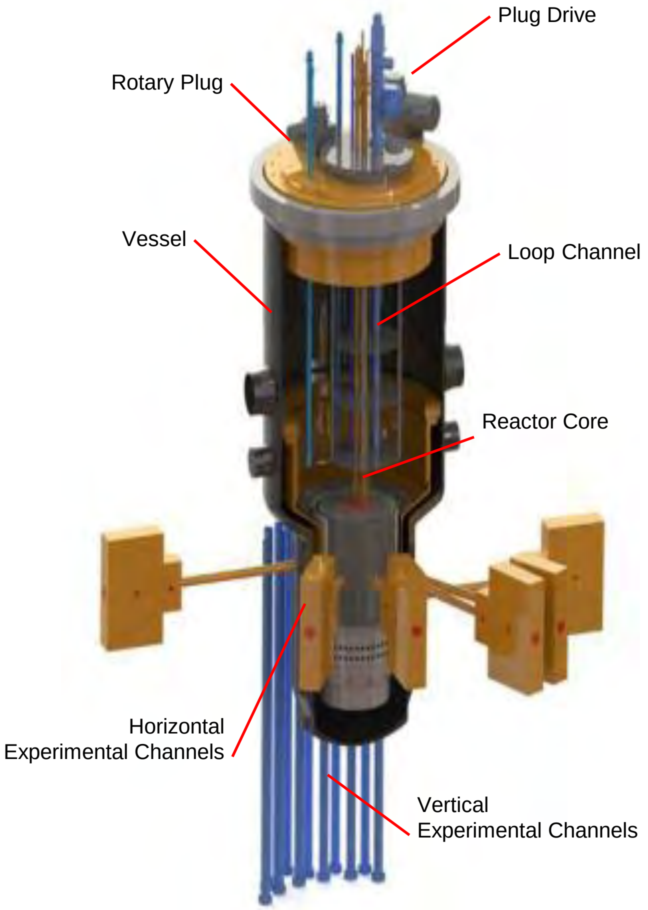
BFS-1 – Benchmark Experimental Complex

MBIR Multifunctional Research Reactor (model)

MBIR – a Unique Multipurpose Research Infrastructure

- Fast neutron spectrum, sodium coolant, MOX fuel, 150 MW(t) heating power, 50 MW(t) electric – reactor MBIR will produce electricity for the local market
- Linear heat rate - max. 500 W/cm, max temp on the cladding 700C
- Min designed life time - 50 years
- Upgradeable experimental capabilities, sockets for experimental devices to be tested in conditions close to real
- Under construction at RIAR - Research Institute of Atomic Reactors, a Rosatom enterprise

Main Technical Capabilities	BOR-60	MBIR
Max. neutron flux, 1015 sec-1 cm-2	2.8	5.3
MTAs in the core	12	14
Instrumented cells	1	3
Outside loop channels	0	3
Vertical and horizontal channels	12	18
Max. dpa rate in central channel (annual)	22	34
Total dpa/l per annum available in the reactor core	300	1350



Partners can sign a separate service contract in respect to post irradiation studies. RIAR research laboratory complex may perform a wide range of post irradiation research on-site removing the implication of the irradiated materials transportation and RAW disposal

Current International Research Center Consortium Status

Rosatom / RIAR

- Operating the reactor
- R&D program execution
- Laboratory assist
- ICERR status from IAEA

Technical services ←

→ Financial resources

International Research Center Consortium

- R&D program administration
- Joint activities management
- Reactor services marketing and PR
- Managing of joint financing
- IP servicing
- NEA OECD multilateral R&D program support

Advantages of International Cooperation

For foreign partners:

- Guaranteed opportunity to conduct research at MBIR after 2020
- Sharing experience and knowledge on fast reactors and reactor experiments
- Platform for experimenting and R&D of national projects of innovative reactors

For global community:

- Possibility of attracting specialists from developing countries to the sphere of fast neutron reactors without any risks for the non-proliferation regime

For Russia:

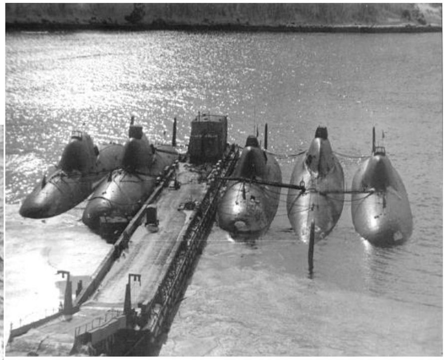
- Attracting additional experience and knowledge at the development stage of the project
- Expansion of interaction between Russian and foreign specialists
- Additional investments for the project

Lead Fast Reactor Development Stages in Russia

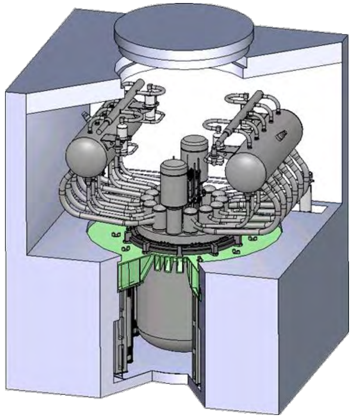
Pb-Bi stand (1951)

Test Submarine ‘Project 645’ (1963)

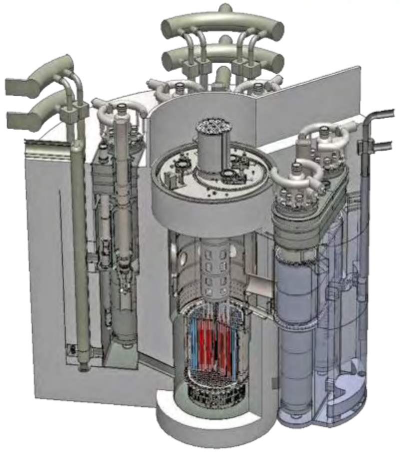
Test Submarine ‘Project 705’ (1971)



Serial Submarine ‘Project 705’ (1976-1996)

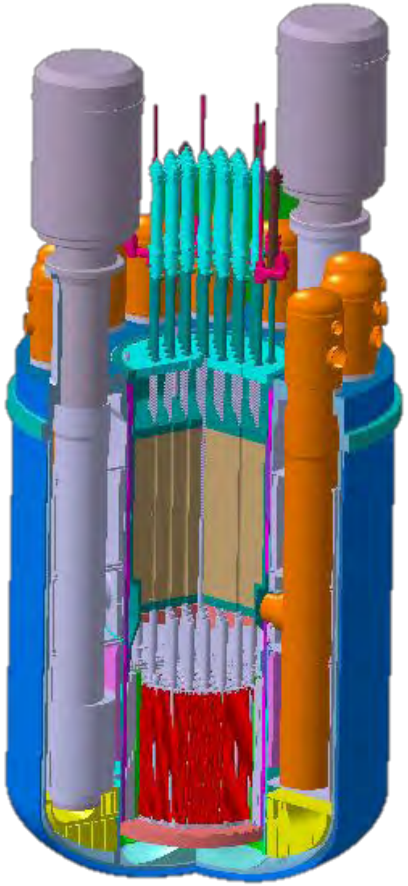


SVBR-100 (after 2025)



BREST-OD-300 (after 2025)

SVBR-100 Reactor



Parameter	Value
Thermal power (rated), MW	280
Temperature, °C at the core outlet at the core inlet	 482 320
Number of fuel rods, items	12114
Average volume power deposition density of the core, kW/dm^3	140
Average linear loading per fuel rod, kW/m	~243
Fuel type Loading of U-235, kg Average enrichment of fuel, at.%	UO_2 1470 16.1
Volume of coolant in primary circuit, m^3	18
Dimensions of reactor module: diameter by height, m	4.53×7.55

BREST-OD-300 Reactor. Scheduled Start-up - after 2021

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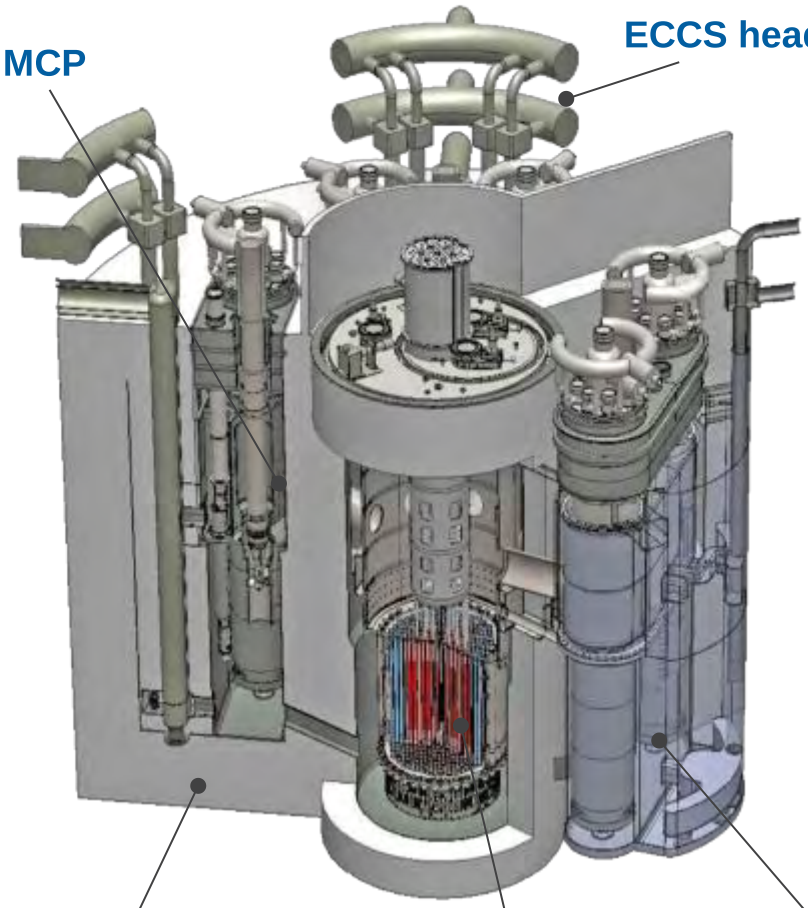


BREST-OD-300: innovative technology solutions

- a new coolant type – chemically inert liquid Pb
- equilibrium core with (U- Pu) nitride fuel:

- low reactivity margin (< $\beta_{эф}$) at the power level that rules out any accident of the Chernobyl type;

- full fuel breeding (BRC within the range of 1.04 – 1.06) without weapons-grade Pu production (no blankets);
- starting with the third year of operation – fuel self-sufficient operation in the closed nuclear fuel cycle;
- possible use (burning) of long-lived MA;

- elimination of coolant loss, a new ECCS type – an accident of "Fukushima" type is impossible

Thermal power, MW	700
Electrical power, MW	300
Steam production capacity t/h, no less	1480
Primary coolant, volume, m3	Lead 1000
Gas pressure above the LC level: -overpressure, MPa - maximum pressure, MPa	0.003-0.005 0,02
Average Pb temperature at the core inlet/outlet,°C	420/540
Average Pb temperature at the steam generator inlet/outlet, °C	340/505
Number of loops	4

Prospects of Nuclear Heating

Currently in Russia
In the Russian climatic conditions heat supply is the most fuel-intensive sector of the economy (more than 40% of the fuel and energy resources).

75% of the consumption of heat energy falls on facilities covered by district heating systems

The use of fossil fuels in heat power has obvious drawbacks:

- **Growing cost** of organic fuel
- **Difficulties in delivering fuel** to remote areas
- **Ecological problems**

Conditions for the effectiveness of nuclear heating systems

- **lowest cost** of installations
- operation of a nuclear power source mainly in the “**basic mode**”
- **simplicity** of manufacturing, installation and construction of equipment
- **minimum time** for design and construction
- **highest safety** - possibility of placing the installation near the consumer
- **easy maintenance** - no need for a large number of personnel

For effectiveness of heat supply systems of the housing and communal services, **special nuclear power installations needed**

Under these conditions, nuclear power may prove to be the most effective source of thermal energy for the needs of housing and communal services

Russian Experience in Nuclear Heating

Russia has obtained successful experience of using nuclear power units for heating

The first NPP in the world with AM reactor (Obninsk)

The first nuclear heating plant (Bilibino)

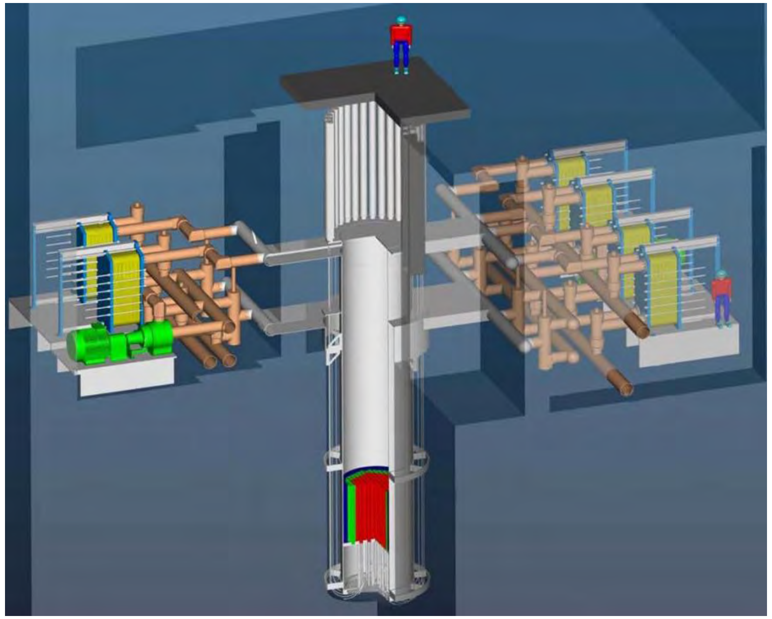
Beloyarsk NPP with BN-600 fast neutron reactor (Zarechnyi)

RUTA Reactor

Reactor Unit for The heat supply with Atmospheric pressure in the primary circuit

Pool reactors do not have excess water pressure in the primary circuit and the reactor pool, which completely excludes the possibility of a number of dangerous emergencies damaging nuclear fuel

Due to high safety indicators, stations with such reactors can be located within inhabited areas and town near the heat consumers



Advantages

single-purpose use – heating supply

simple design
(pool reactor and
low pressure and temperature of primary circuit heat carrier)

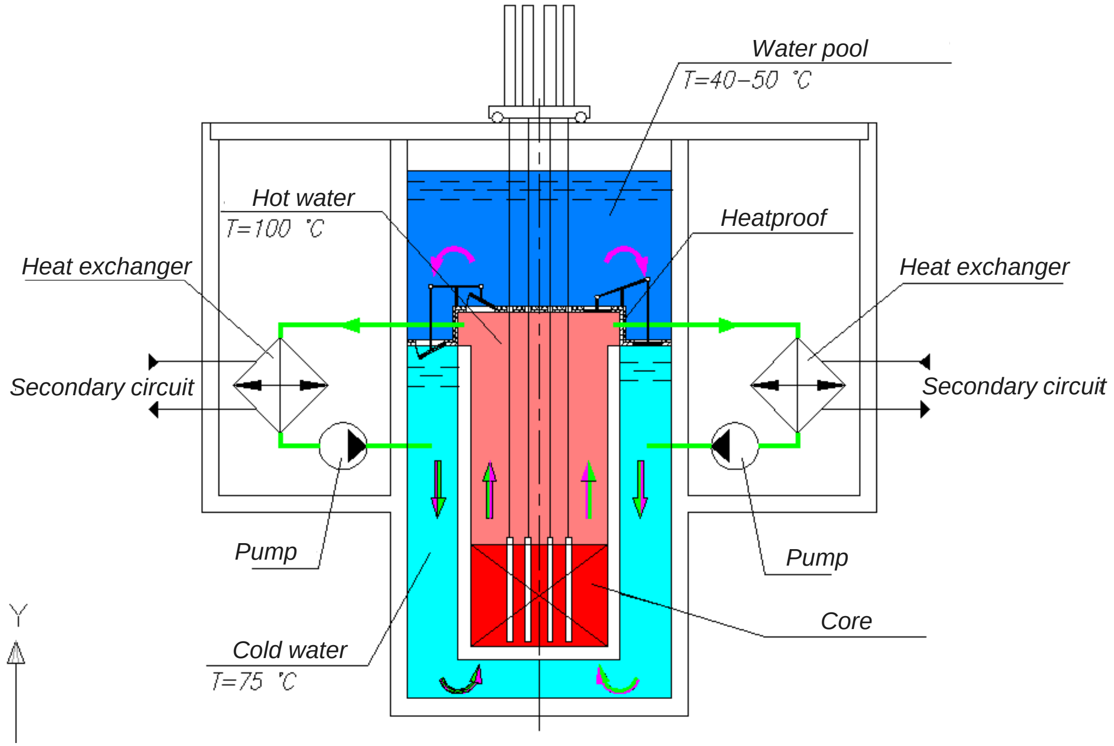
reliability and safety
(a three-circuit scheme for transferring heat to the consumer, a large accumulating water deposit in the pool, feedback reactivity effects and natural circulation in emergency conditions)

low cost

- **Serially manufactured nuclear and non-nuclear equipment** is used
- Nuclear fuel based on low-enriched uranium dioxide **similar to that for VVER-type reactors**
- **Integrated offer**: possibility to implement a **full cycle of operation and maintenance of RUTA reactors**, including service and SNF management

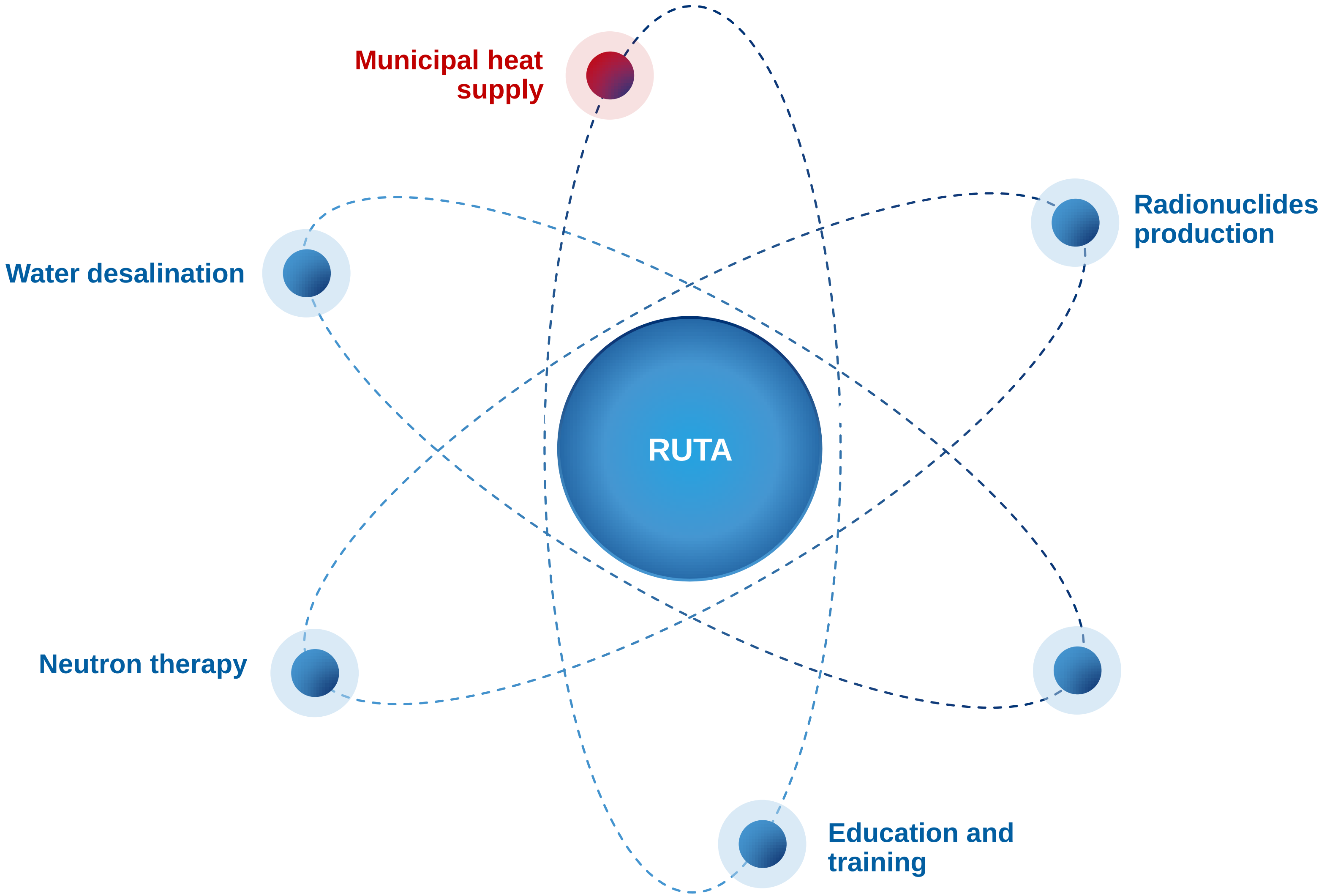
RUTA Technical Specifications

Thermal power of the reactor	20 – 70 MV
Fuel	UO_2 / cermet
U-235 enrichment, %	3.6 / 5.4
Fuel life cycle	9 (30) years
Period between refueling	3 (10) years
Core temperature (input/output)	75 / 101 °C
Amount of circuits	2
Annual heat supply (Capacity factor=0.66)	100 – 350 thousand Gcal
Life cycle	60 (100) years



Principal hydraulic scheme of the primary circuit

Use of RUTA can be extended



Japanese Hydrogen Plans

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Japan – one of the leading countries in the field of hydrogen and hydrogen technologies development.

Japan aims to build **"hydrogen economy"** and realize "**hydrogen society**" by 2020.

Japanese hydrogen plans up to **10 mln t** in **2050**.

"Basic Hydrogen Strategy" - step by step demonstration approach to local hydrogen market development

- **SUPPLY CHAINS COMMERCIAL STAGE**
- **DEVELOPMENT OF DOMESTIC P2G TECHNOLOGIES**

PRESENT	2030	TARGET

SUPPLY CHAIN DEVELOPMENT AND DEMONSTRATION, SCALE-UP

Applications:

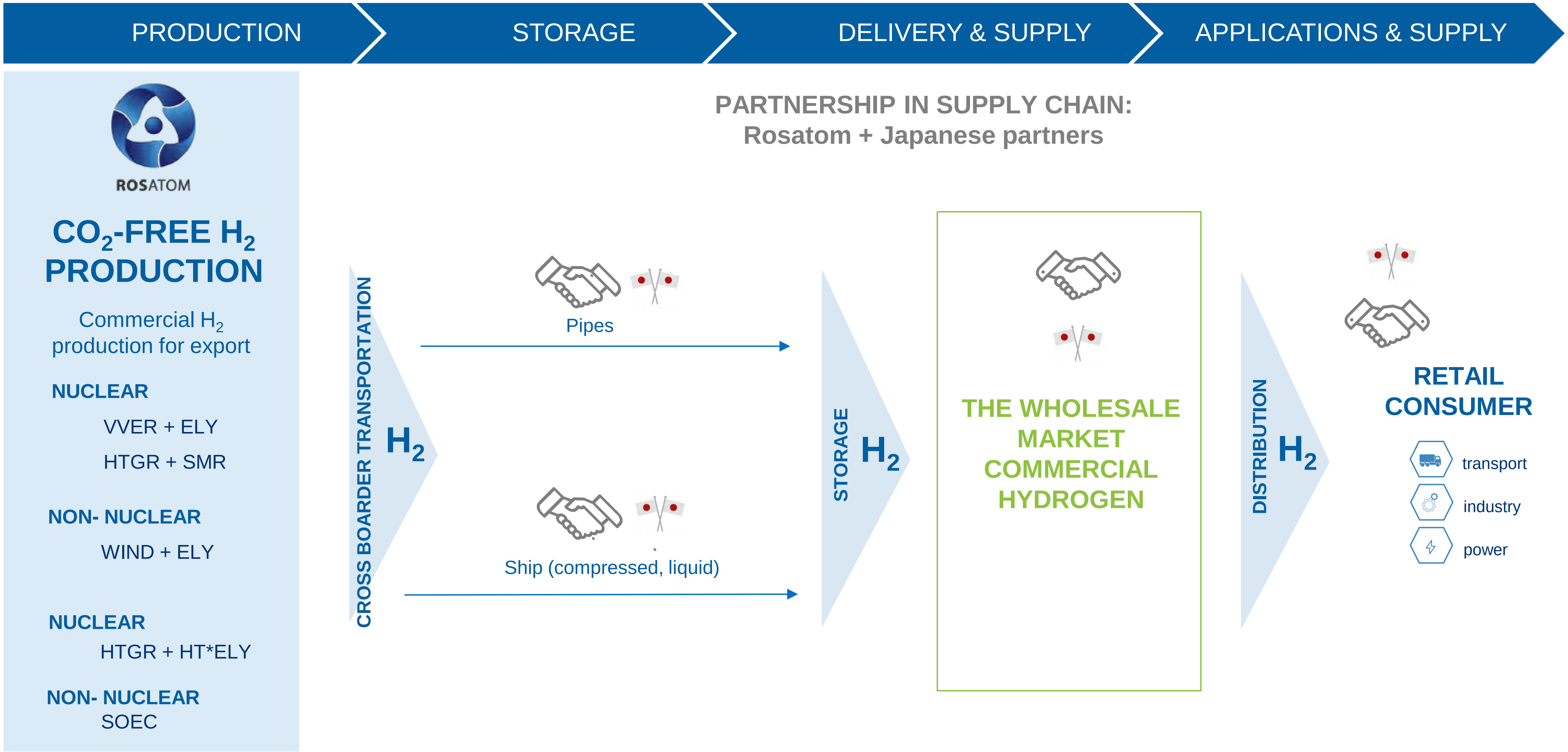
TRANSITION TO A CO2-FREE TECHNOLOGIES FOR THE ENTIRE PRODUCTION CHAIN

Large scale applications:

RUSSIA CAN BECOME ONE OF RELIABLE SUPPLY CHAIN PARTNERS TO JAPAN

Source: METI: Basic Hydrogen Strategy (key points)

Rosatom is Ready to Cooperate



- Potential for cooperation

Contacts

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