ROSATOM OVERSEAS

ROSATOM OVERSEAS INC

Benefits of the Integrated Solution for Construction and Operation of Research Reactors and Centers of Nuclear Science and Technologies

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WHY GO INTO NUCLEAR RESEARCH?

To host **ground-breaking experiments,** improve overall scientific knowledge and serve as **training centres** for students and nuclear scientists of the future

To solve developmental challenges in **health care, agriculture and industry**.

To foster **national, regional and international** technology exchange and innovation.

To **improve the national economy** through application of the advanced nuclear technologies

To develop the skills & expertise for **industrial nuclear energy use**

To **upgrade the public image** of the country on the regional and international scale

WHY GO WITH ROSATOM INTO RESEARCH REACTORS?

For over **50** years, research reactors have been fostering scientific innovation and education in more than **50** countries worldwide

There are **245** research reactors in operation worldwide

Rosatom has built **120** research reactors in Russia & abroad

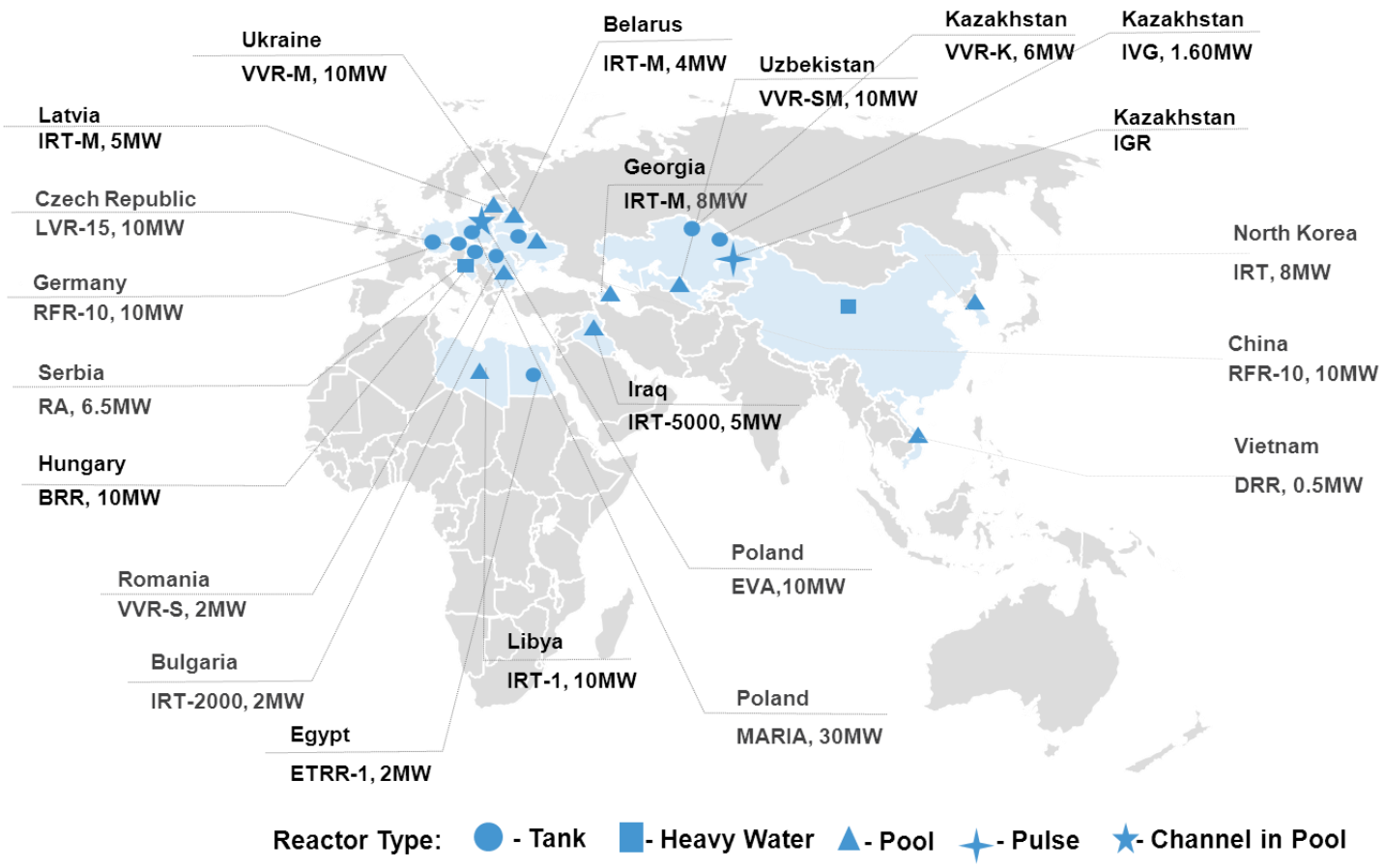
Over 50 research facilities are in operation in Russia

In-house capabilities to develop and supply research and training **labs**

Broad on-the-job **training facilities** at research and commercial research reactors

20 000 employees in Rosatom enterprises and R&D institutions are supporting Rosatom scientific and research platform and cooperation with partner-countries

RUSSIAN RESEARCH REACTORS OVERSEAS



- **Over 100 research reactors were built in Russia, 52 of them are still being operated – about 20% of the world number of RR**
- **More than 20 research reactors were built abroad in cooperation with Russia and on the basis of Russian designs. The majority of these reactors is in operation**

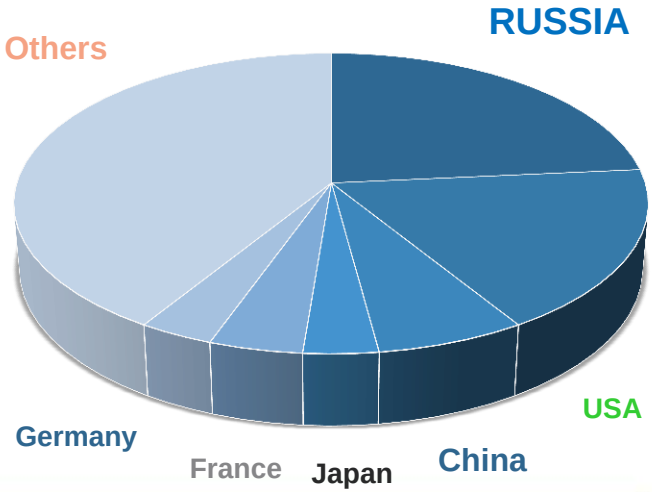
RESEARCH REACTORS IN RUSSIA (ROSATOM/TOTAL)

Name	Operating	Safe Enclosure	Under Construction	Total
Research Reactors (steady state and pulse)	19/28	1/1	2/3	22/32
Zero-Power Reactors (Critical Assemblies)	12/24	1/1	0	13/25
	31/52	2/2	2/3	35/57

Seven from eight steady state operating reactors with power not less than 10 MW belong to ROSATOM

Different types, power, utilization…

Operating Research Reactors in the World

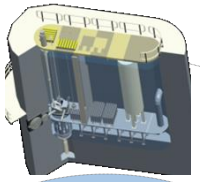


ROSATOM UNIQUE INTEGRATED SOLUTION FOR RESEARCH REACTORS AND CENTERS OF SCIENCE AND TECHNOLOGIES

ROSATOM

Technical Solution

- Modern design
- Construction and life cycle management support (fuel, services, modernization)
- Operation & maintenance



Industrial Solution

- Equipment manufacturing, service & works localization,
- Technology transfer,
- Certification of local suppliers, participation in Rosatom third countries projects

Financial Solution

- Project finance structuring
- State credits
- Partnership schemes

Knowledge, skills, human capital

- Personnel education & training (incl. onsite training),
- R&D base development,
- Operation experience exchange

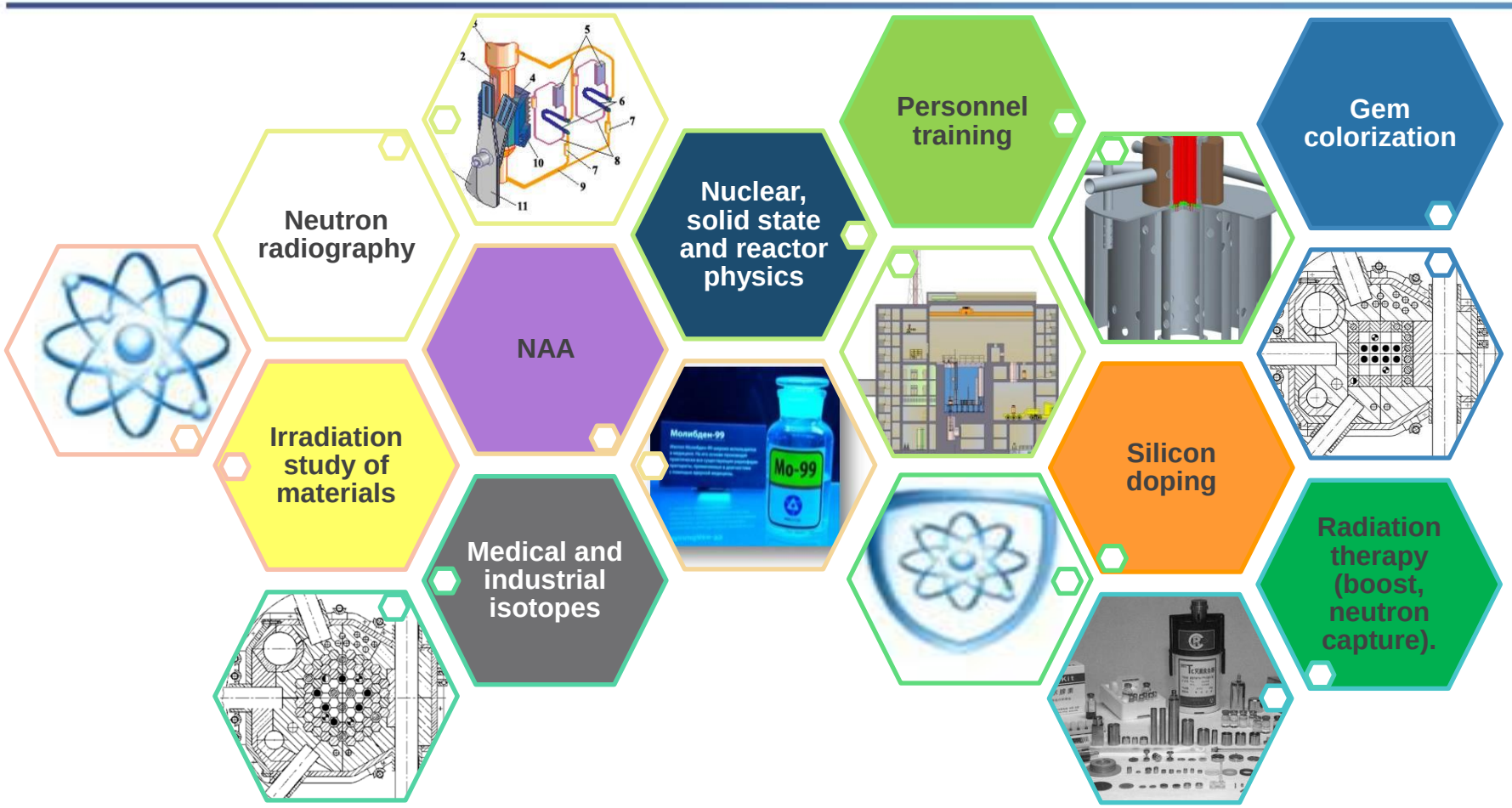
Regulation, Infrastructure and Public acceptance

- Creation and development of regulatory base
- Spent nuclear fuel and radioactive waste management
- Social-political programs support

ROSATOM Integrated Solution for Research Reactors

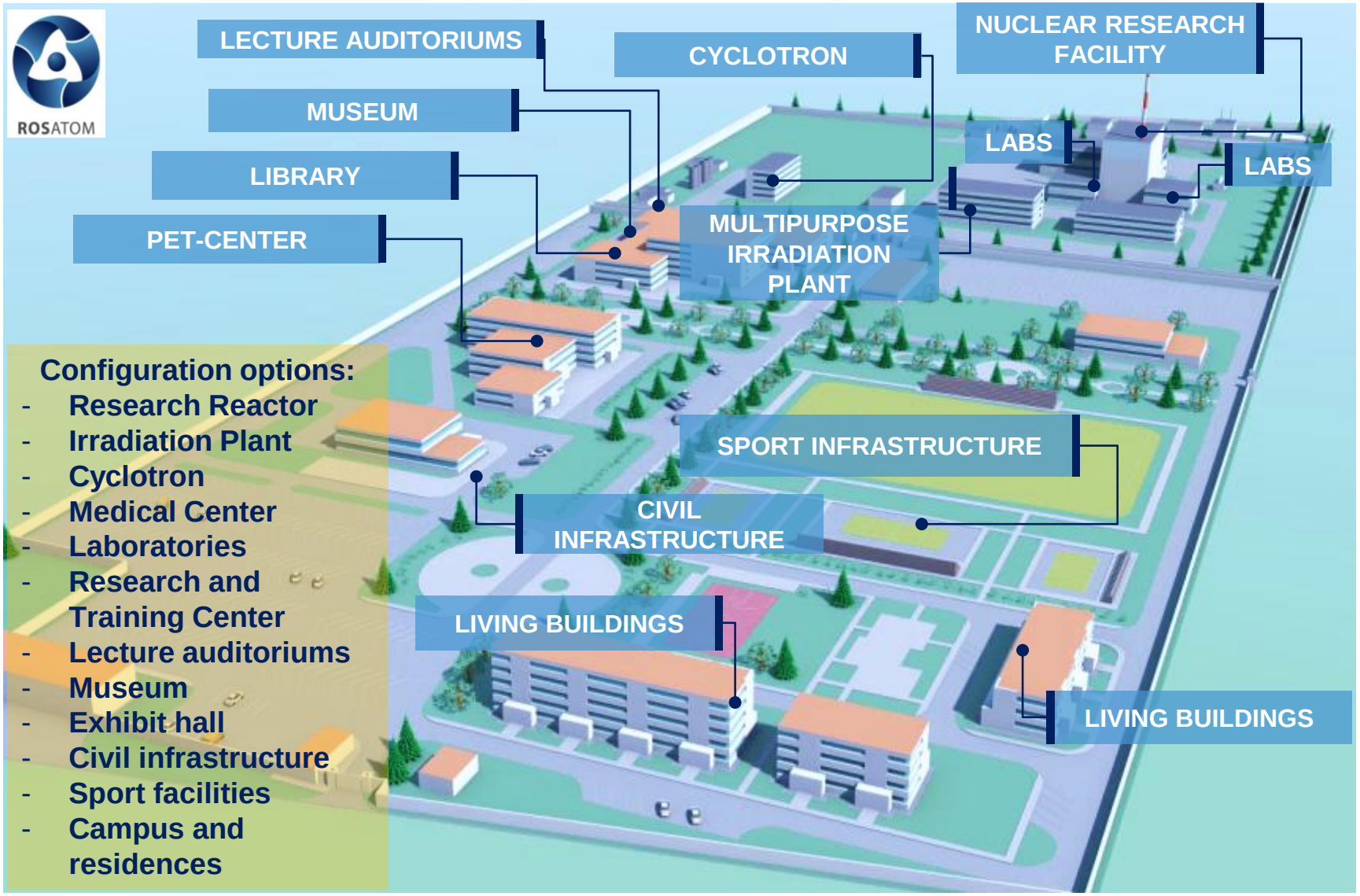
SAFETY
- basic principle

IDENTIFICATION OF POTENTIAL CUSTOMERS



Customers and their needs are important to be identified to elaborate a sound and efficient technical proposal: training/science vs. training/science/business

OPTIONAL CONFIGURATIONS FOR CENTERS OF NUCLEAR SCIENCE AND TECHNOLOGIES



Configuration options:

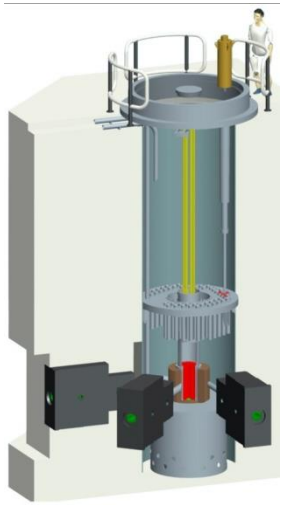
- Research Reactor
- Irradiation Plant
- Cyclotron
- Medical Center
- Laboratories
- Research and Training Center
- Lecture auditoriums
- Museum
- Exhibit hall
- Civil infrastructure
- Sport facilities
- Campus and residences

TECHNICAL SOLUTION: RESEARCH REACTORS CAPACITY RANGE

up to ≈ 1 MW

1

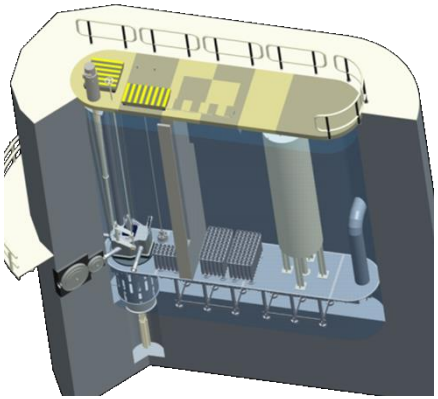
TRAINING RESEARCH REACTOR



≈ 10 MW

2

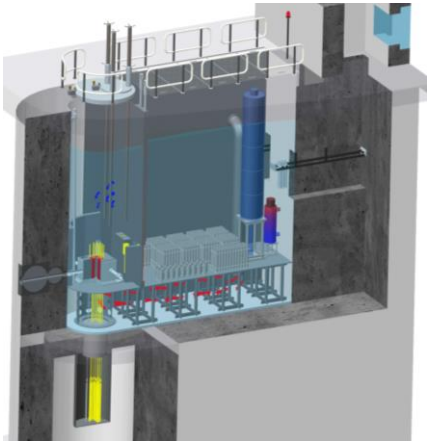
BASIC MULTIPURPOSE RESEARCH REACTOR



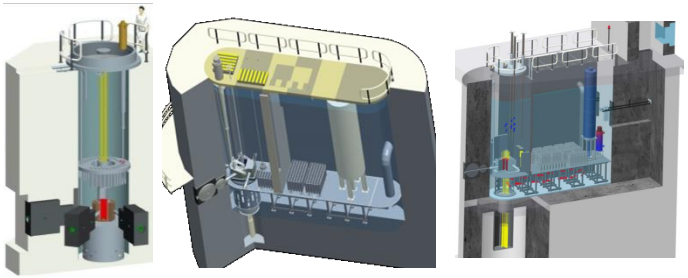
≈ 20 MW

3

ADVANCED MULTIPURPOSE RESEARCH REACTOR



CAPACITY RANGE KEY CHARACTERISTICS

Key features of research reactors	up to 1 MW	10 MW		20 MW	
Fuel assembly type	VVR-M2	IRT-4M	VVR-KN	IRT-4M	VVR-KN
Fuel assembly number	70	16	26	40	45
Fuel enrichment, U235, %	19,7				
Maximum thermal neutron flux, x10^{14} 1/cm^{2}s:					
in the core	0.45	3.2	3.3	> 4.1	> 4.6
in Be reflector	0.22	2	2	> 1.4	> 1.2
Reactor service life, years	50				
Coolant	Demineralized water				
Reflector	Beryllium				
	**1 TRAINING RESEARCH REACTOR**	**2 BASIC MULTIPURPOSE RESEARCH REACTOR**		**3 ADVANCED MULTIPURPOSE RESEARCH REACTOR**	

REACTOR LABORATORIES AND TECHNOLOGIES

Laboratories	Experiments/Testing		1 MWt	10 MWt	> 10 MWt
Neutron Activation Analysis (NAA) Lab	Neutron Activation Analysis (NAA)		+	+	+
	NAA by Instant Gamma Radiation		-	+	+
	Age Determination by Argone	Age Determination	-	+	+
	Fission Trace		-	+	+
Radioisotope Lab	Boron Neutron Catching Therapy		+	+	+
	Positron Source		-	+	+
	Isotope Production		-	+	+
Material Centre	I&C Testing and Calibration		+	+	+
	Materials		-	+	+
Irradiation Center	Silicon Doping	Transmutation Effects	-	+	+
	Gamma Irradiation		-	+	+
	Gemstone Coloring		-	+	+
	Neutron Tomography	Testing	-	+	+
	Neutron Diffraction Analyses		-	+	+
	Fuel		-	-	+

MULTIPURPOSE IRRADIATION CENTERS

Center of Irradiation – commercial industrial facility which provides irradiation services by means ionizing radiation.

Radiation Treatment:

- Used in more than 50 countries
- Environmentally safe
- High productivity and efficiency of the process
- Increase of the trade between countries due to the strict requirements of countries-importers to the products quality

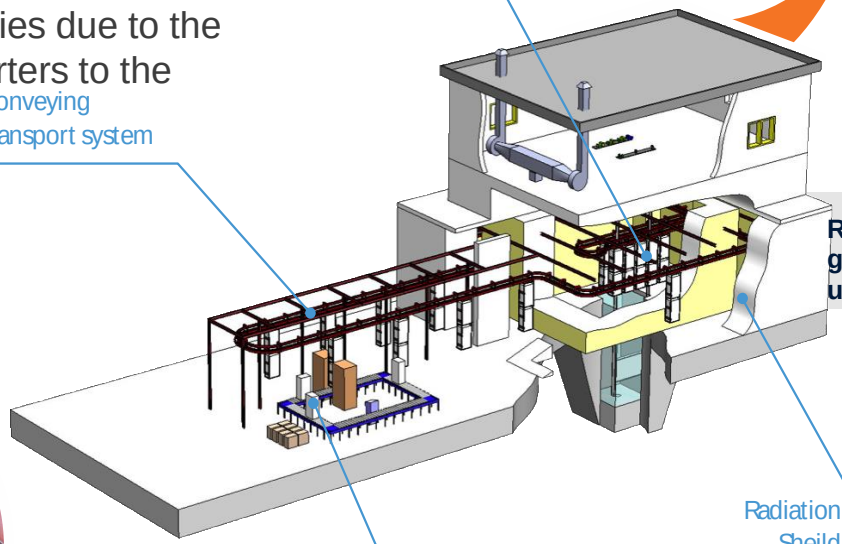
Main fields of application:

- Sterilization of medical goods
- Food decontamination of food
- Modification of materials

Delivery of goods

Storage and shipment of goods

- Products shipment to the warehouse for a short – or long-term storage, depending on the the contract terms
- Loading products in vehicles directly from the warehouse



Radiation treatment of goods on the gamma-ray unit or electron accelerator

- Automated process of loading goods on the conveyor
- Delivery of goods to the zone of irradiation
- Automated unloading of goods

Medical infrastructure

Diagnostic facilities: 3 variants of units
-PET diagnostics department;
-SPECT diagnostics department;
-Complex radionuclide diagnostics solution, including cyclotron and radiochemistry facility, PET/CT, SPECT and SPECT/CT.

Therapeutic facilities
-Interstitial and endocavitary radiation therapy department equipped with «Agat–VT» brachytherapy system;
-Radionuclide therapy department (use of radiopharmaceuticals with iodine-131, samarium-153 and strontium-89).

Complex solutions for GMP radiopharmaceuticals (RF) production
-Cyclotron-based PET RF production;
-Reactor-based RF production.

RADIOPHARMACEUTICALS PRODUCTION ON MCC-30/15 CYCLOTRON

Radiopharmaceuticals facility can be set up on the basis of on the medium energy MCC-30/15 cyclotron (30 MeV).

One of the possible configuration provides the country medical unites with PET and SPECT and therapy radiopharmaceuticals with: ^{22}Na, ^{38}K, ^{57}Co, ^{67}Ga, ^{68}Ge, ^{73}Se, $^{75\text{-}77}Br$, ^{81}Rb (^{81}Kr), ^{111}In, ^{123}I, ^{201}Tl, ^{225}Ac, ^{18}F, ^{11}C, ^{15}O, ^{13}N.

The last four are assigned especially for PET pharmaceuticals.

There are configurations on the base of other cyclotrons of less energy: CC18/9M and CC-12.

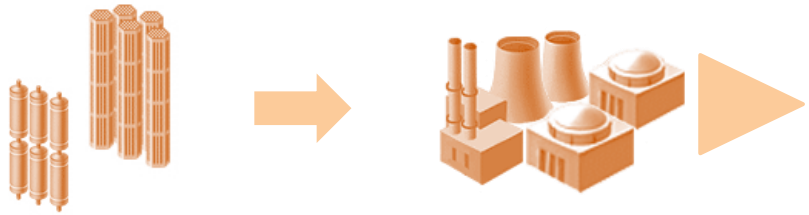
Research reactor integrated into Centers of Nuclear Science and Technologies

- Nuclear Infrastructure and Regulation
- Design, Engineering and Construction
- Training and Education
- Service and Maintenance
- Fuel and Radioactive Sources supply
- Radioactive Waste and Spent Fuel Management
- Decommissioning

Continuous full lifecycle support from Rosatom

ROSATOM INTEGRATED NFC SOLUTIONS

Usual Nuclear Fuel Cycle supply approach

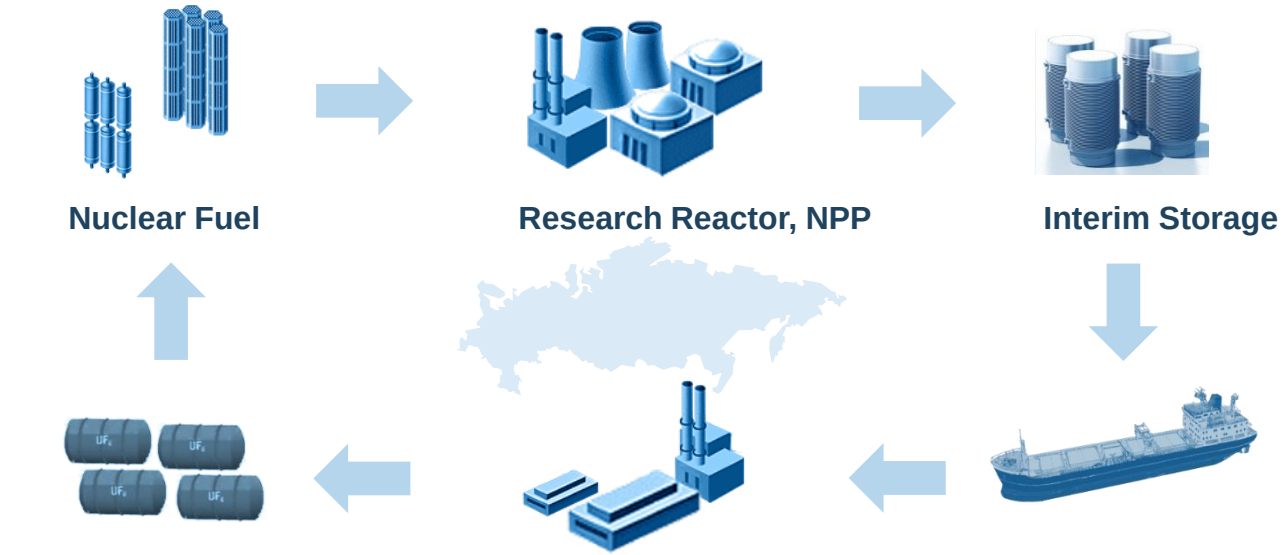


Nuclear Fuel — Research Reactor, NPP

Issues for the Customer

- Wet short-time SNF storage or dry long-time one?
- Reprocessing or final disposal?
- How and where to pack RW?
- How to ship the SNF?
- What should be the mode of decommissioning?
- What to do with reprocessed U and Pu?

Rosatom Integrated Nuclear Fuel Cycle proposal

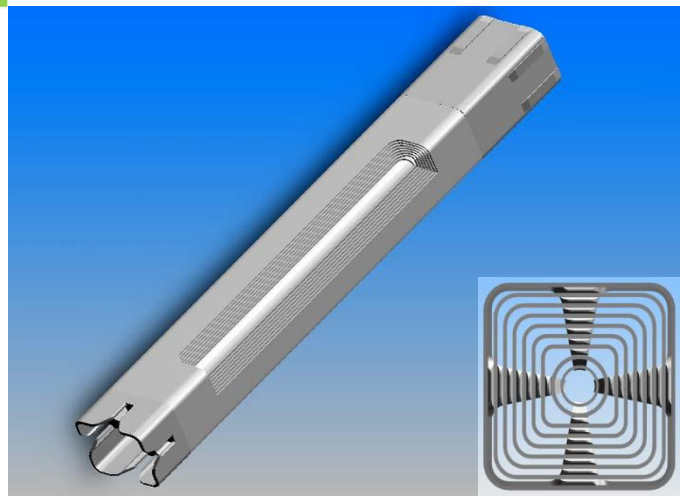


ROSATOM FUEL FOR RESEARCH REACTORS: LIFETIME FUEL SUPPLY GUARANTEE

NF for research reactors: Russian design

- Design & Fabrication of nuclear fuel for reactors in Russia
- For overseas research reactors of Russian design (8 countries) fuel assemblies with enrichment in U235 < 20%
- Participation in RERTR Program (conversion of research reactors using HEU fuel to LEU, U235 < 20%)

NF for research reactors: foreign design



- Fabrication of MTR fuel assemblies with plate-type fuel elements for research reactors of the Western design
- P20 fuel assemblies manufactured at NCCP by extrusion technology. NCCP qualification was completed in 2014

Fuel assemblies are delivered to customers in transport casks complying with IAEA regulations by all modes of transport including air

RESEARCH REACTOR MODERNIZATION & UPGRADES

Key Services for RR Upgrades

Ageing management / Lifetime extension

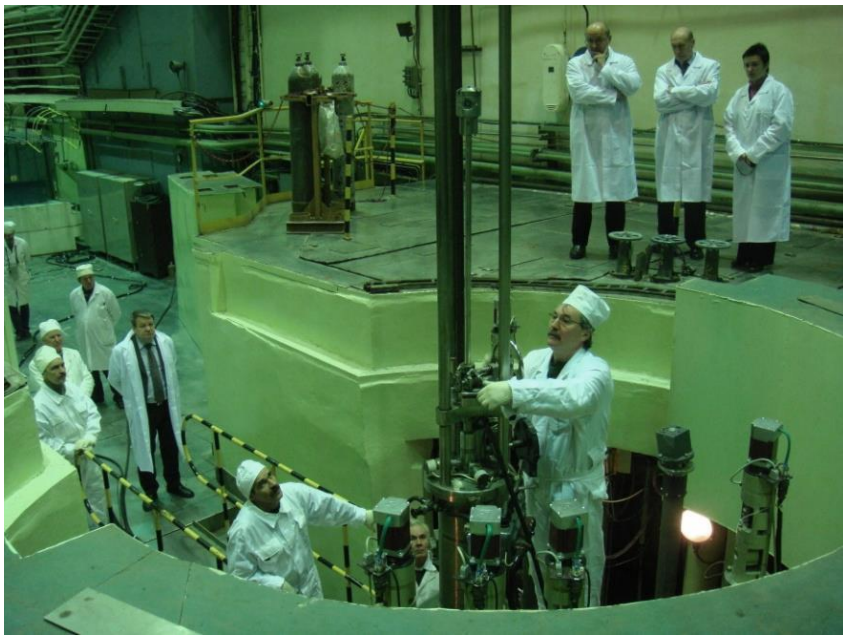
Capacity Increase

New functional facilities

Key equipment replacements: neutron sources, reflectors, etc.

Core modernization for alternative fuel supplies

IBR-2M research reactor (2011) is an upgraded IBR-2 fast pulsed reactor reactor (1984) with movable reflector and record high thermal neutron flux of 10^{16} $cm^{-2} \cdot s^{-1}$



Restart after modernization on February 11, 2011

BOLIVIA – CENTRO DE INVESTIGACIÓN Y DESARROLLO EN TECNOLOGÍA NUCLEAR (CIDETEN)

El Alto, Bolivia

- **Legal basis** – Intergovernmental Agreement (signed March 6, 2016)
- First RR at 4100 m altitude

- **Nuclear Research Reactor (up to 200 кW)**
- **Multipurpose Irradiation Center**
- **Cyclotron**
- **Scientific and human capacity development labs**
- **Engineering complexes and systems**
- **Social and educational facilities**

Thank you!