strategy&

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Round Table: Creation of Nuclear Science and Technology Centers on research reactor basis. Business and scientific application.

Research reactors and development of peaceful international nuclear industry

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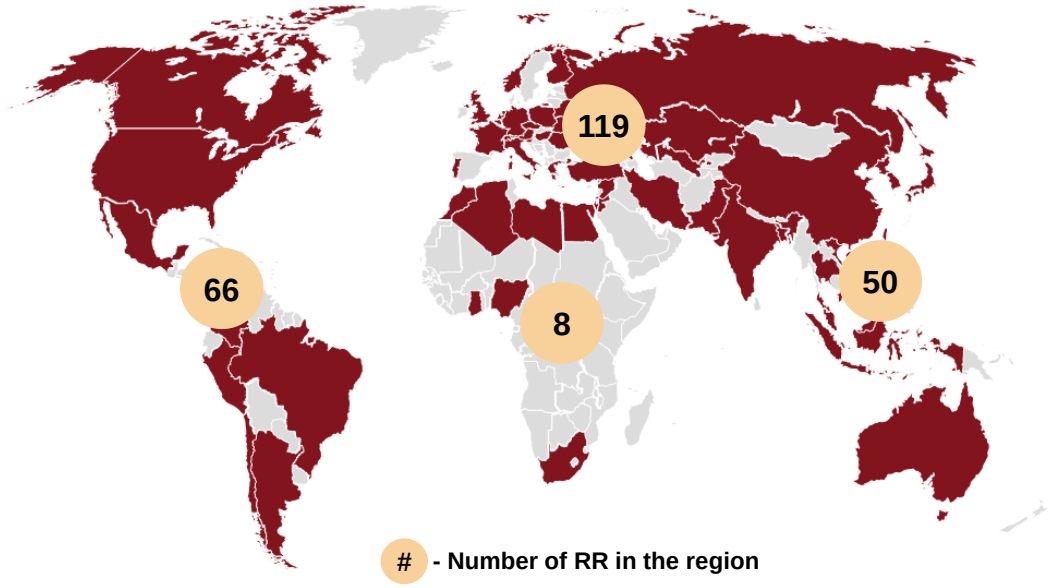
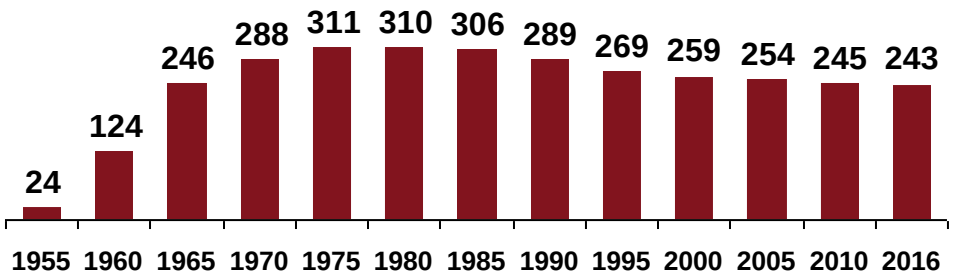
There are 243 research reactors operating in 56 countries around the world

Countries with Operating Research Reactors



Number of Operating Research Reactors



Comments

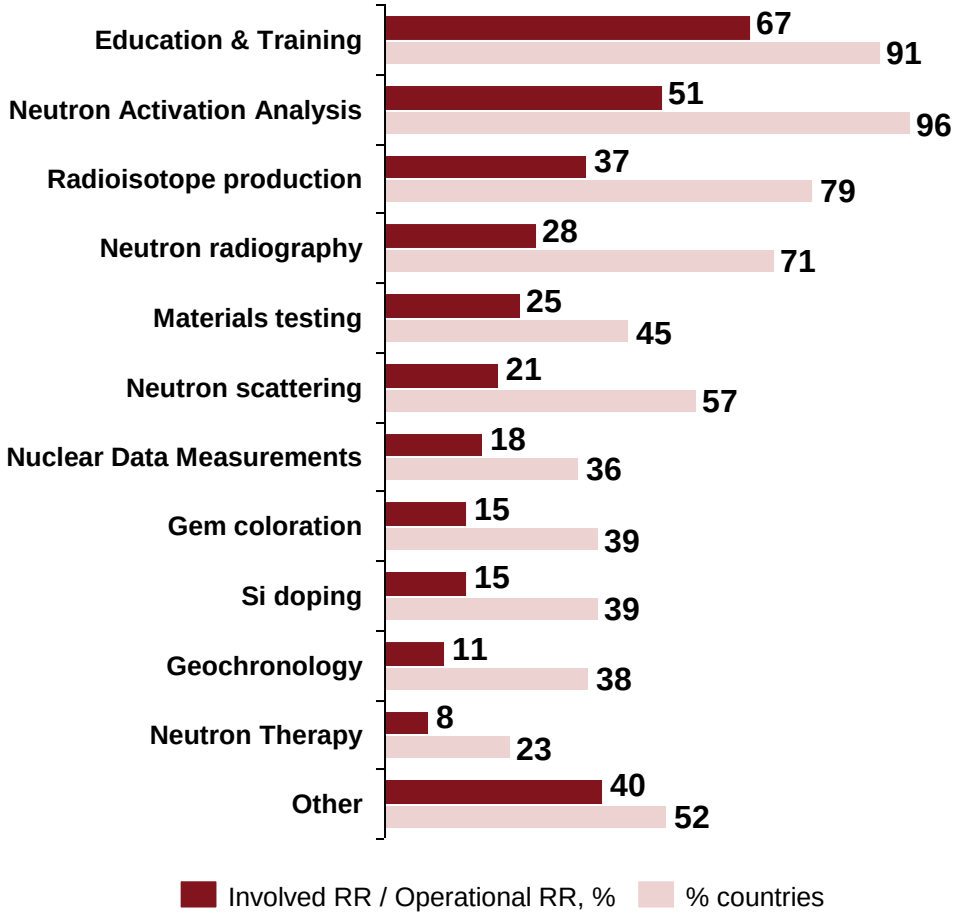
- Research reactors are nuclear reactors that serve primarily as a neutron source
- In 2016*, Russia has most operational research reactors (63), followed by USA (42), China (17), Japan (8), and Germany (8)
- Many developing countries also have research reactors, including Bangladesh, Algeria, Colombia, Ghana, Jamaica, Libya, Thailand and Vietnam.
- 18 more reactors are planned or under construction

** Research Reactor Database data (IAEA)*

Source: Research Reactor Database, IAEA

Research Reactors most frequently serve for Education, Neutron Activation Analysis and Radioisotope Production

RR applications structure by reactors and countries, %, 2015



Comments

- Research reactors are simpler than power reactors and operate at lower temperatures – their main purpose is to provide a neutron source for research and other purposes
- Many of the world's nuclear reactors are used for research and training, materials testing, or the production of radioisotopes for medicine and industry

Source: Research Reactor Database, IAEA

Some research reactors being a part of nuclear research and technology centers can also be successfully used on commercial basis

SELECTED EXAMPLES

NRU

Canadian Nuclear Laboratories
Laboratoires Nucléaires Canadiens

Location: Canada

Opened: 1957

Power: 135 MW

Type: Tank

Utilization: >300 days/year

- NRU is responsible for production of **40%** of **Mo-99 worldwide,** past **shutdowns** resulted in **supply shortages** in North America
- NRU produces about **75%** of the global supply of **Cobalt-60**, **50%** of **Technetium-99m**
- NRU also produces isotopes like xenon-133, iodine-131, iodine-125, carbon-14 and iridium-92 used for multiple purposes
- NRU is also used for **neutron beam research**, **fuel and materials testing**

SAFARI-1

necsa
We're in your world

Location: South Africa

Opened: 1965

Power: 20 MW

Type: Pool

Utilization: >300 days/year

- South Africa is the **first country** in the world to successfully implement **commercial scale** LEU-based **Mo-99** and **I-131 production**
- SAFARI-1 is **responsible for 10%** of the world's total **production of Mo-99**
- SAFARI-1 is also used for **support services** such as **neutron radiography, neutron diffraction** and **neutron activation analysis**

Source: Research Reactor Database, IAEA, NECSA, CNL, public sources

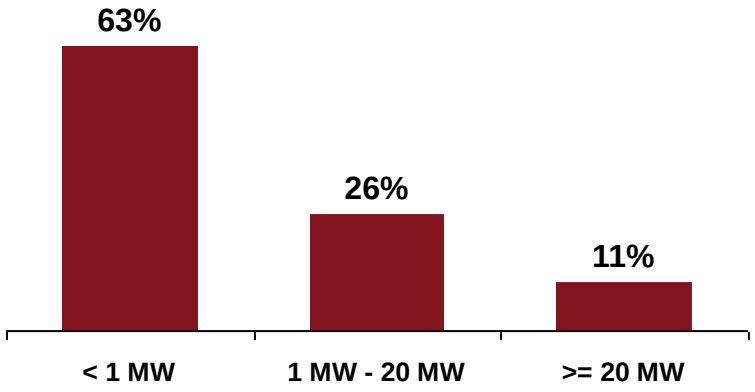
There is a variety of different reactor technologies that can be grouped in 5 categories

Category	Technical distinction	Reactor examples	% of total amount
Pool	Core is submerged in a pool of water that usually provides cooling, moderation and shielding. Includes TRIGA, SLOWSPOKE and MNSR reactors	**TRIGA II Vienna** (Austria) **SLOWPOKE-2** (Canada) **NIRR-0001** (Nigeria) **RBT-6** (Russia)	**~40%**
Tank	Core is located within a closed tank, which is generally made of aluminum or steel. Includes Heavy Water, ARGONAUT and PWR reactors.	**RA-1** (Argentina) **GAMMA** (Russia) **Es Salam** (Algeria) **EWG 1** (Kazakhstan)	**~20%**
Critical assemblies	Heterogeneous reactors, usually operated at source multiplication levels, just below or at criticality	**KVANT** (Russia) **ENTC HWZPR** (Iran) **Flattop** (USA) **Giacint** (Belarus)	**~25%**
Fast	Characterized by the lack of a moderator	**CEFR** (China) **Joyo** (Japan) **BOR-60** (Russia) **FBTR** (India)	**~5%**
Other	Reactors not covered above: graphite, homogenous and other types	**HTR-10** (China) **IIN-3M** (Uzbekistan) **ARGUS** (Russia) **IGR** (Kazakhstan)	**~10%**

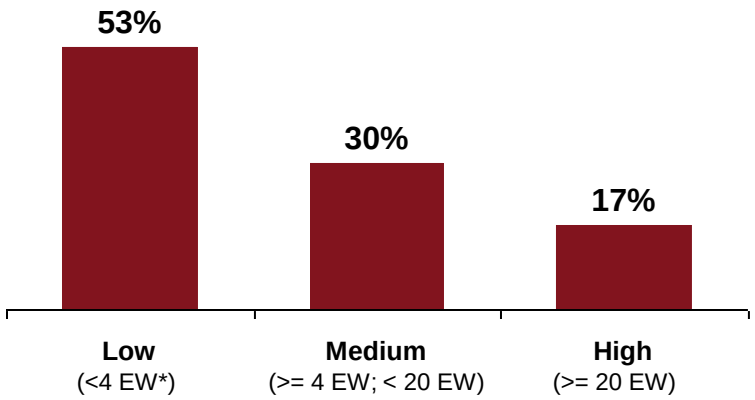
Source: Research Reactor Database, IAEA publications

Research reactors are usually low power reactors utilized at a lower rate compared to commercial NPPs

RR structure by thermal power, %



RR structure by utilization rate, %



Comments

- Most research reactors range up to 100 MW_{th}, compared with 3 GW_{th} for a typical power reactor (i.e. 1 GW_e)
- The total power of all the world's research reactors is little over 3 GW_{th}

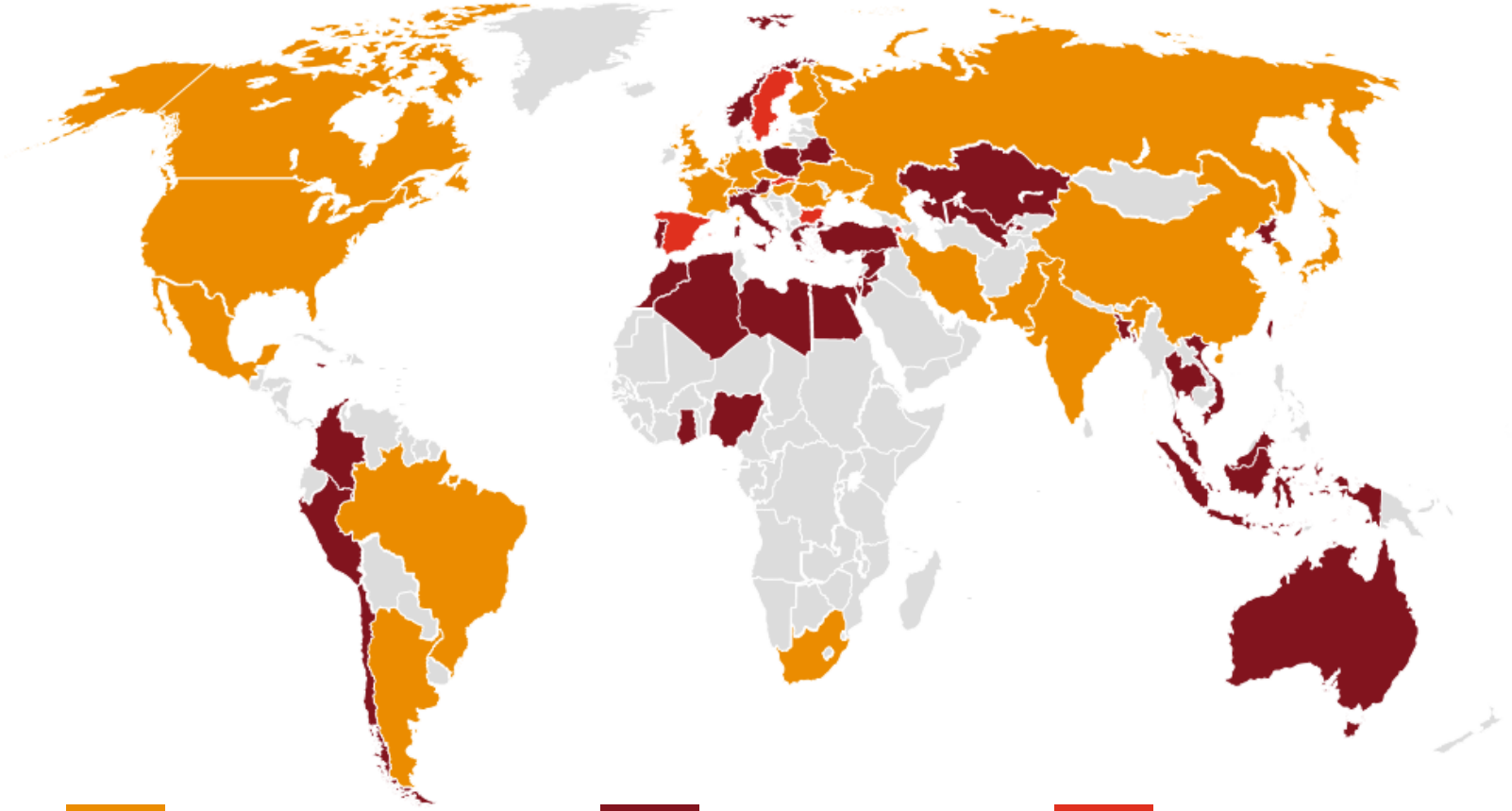
- Current levels of RR utilization provide opportunities for wider uses in terms of commercial and knowledge sharing purposes
- Underutilized research reactors' owners create coalitions, centers of excellence and provide shared access to countries without RR

** Effective Weeks (EW=7days*24hours of operation)*

Source: Research Reactor Database, IAEA

Half of all the countries with research reactors already have commercially operating NPPs, vast majority of others plan to build new NPP soon

Nuclear countries structure by types of reactors possessed



25 - Countries with both RR and NPP

31 - Countries with RR only

5 - Countries with NPP only

Source: Research Reactor Database, IAEA

Research reactors and nuclear research centers usually serve as a starting point for a nuclear program by helping to build relevant expertise…

National position	• The assessment of actual needs for a research reactor and the development of user communities • Development of nuclear infrastructure and integrating it into country's economy
Nuclear safety and security	• Development of domestic expertise in establishing a nuclear safety culture and programs • Getting into the global nuclear safety regime • Involvement of all the relevant stakeholders
Regulatory and legislative framework	• Establishment of independent regulatory authorities • Development of relevant laws, policies and programs • Adoption of international regulatory standards
Human resources	• Development of national human resource to successfully manage nuclear facilities and materials • Adopting the world's best practices and learning how to apply it

…which is reflected in the comments of leadership of nuclear industry's "new comers"

Country Leaders on Research Reactors and Nuclear research centers' role and purpose – Examples

*"The construction and the implementation of this center will allow our country to make a **leap in the scientific and technological** spheres"*

President of Bolivia

*"Establishment of Jordan's first nuclear research reactor came in order to **build** Jordanian and Arab **capacities in the nuclear energy domain**, namely in the medical field"*

King of Jordan

*"Nuclear Research Center is to be created taking into account the necessity of ensuring the use of nuclear technologies for peaceful purposes, **improving financial and technical resources** of the nuclear technologies sector, **increasing highly-qualified human resources** and expanding nuclear research in the country"*

President of Azerbaijan

Note: not direct quotes
Source: public sources, Strategy& analysis

Today's round table will highlight two main areas

- **Countries starting development of own nuclear programs:**
  - What are the key prerequisites for success of research reactor implementation?
  - What challenges do countries face while building their first research reactor?
  - What nuclear infrastructure requirements are being imposed by the new research reactor project?
- **Countries with research reactor development experience:**
  - What are the benefits of commercial and scientific application of the research reactor?
  - What role does research reactor play in development of country's nuclear program?
  - What are the future prospects for research reactors' technologies?