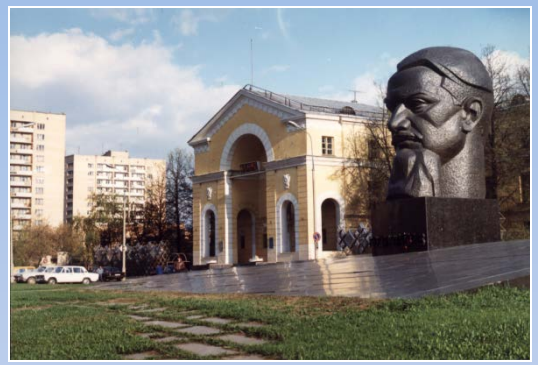
National Research Centre
"Kurchatov Institute"



The role of advanced nuclear power technologies in reducing environmental impacts

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Round table: Eco-efficient technologies of nuclear industry
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Nuclear reactors in the world and in Russia

Mankind has achieved the greatest progress by focusing on one of the reactor technologies, making it the most advanced, and accumulating the largest body of knowledge and experience. These are water-moderated water-cooled pressure vessel reactors which now comprise about 95 % of the global reactor fleet (taking into account marine power systems where only PWR reactors are used).

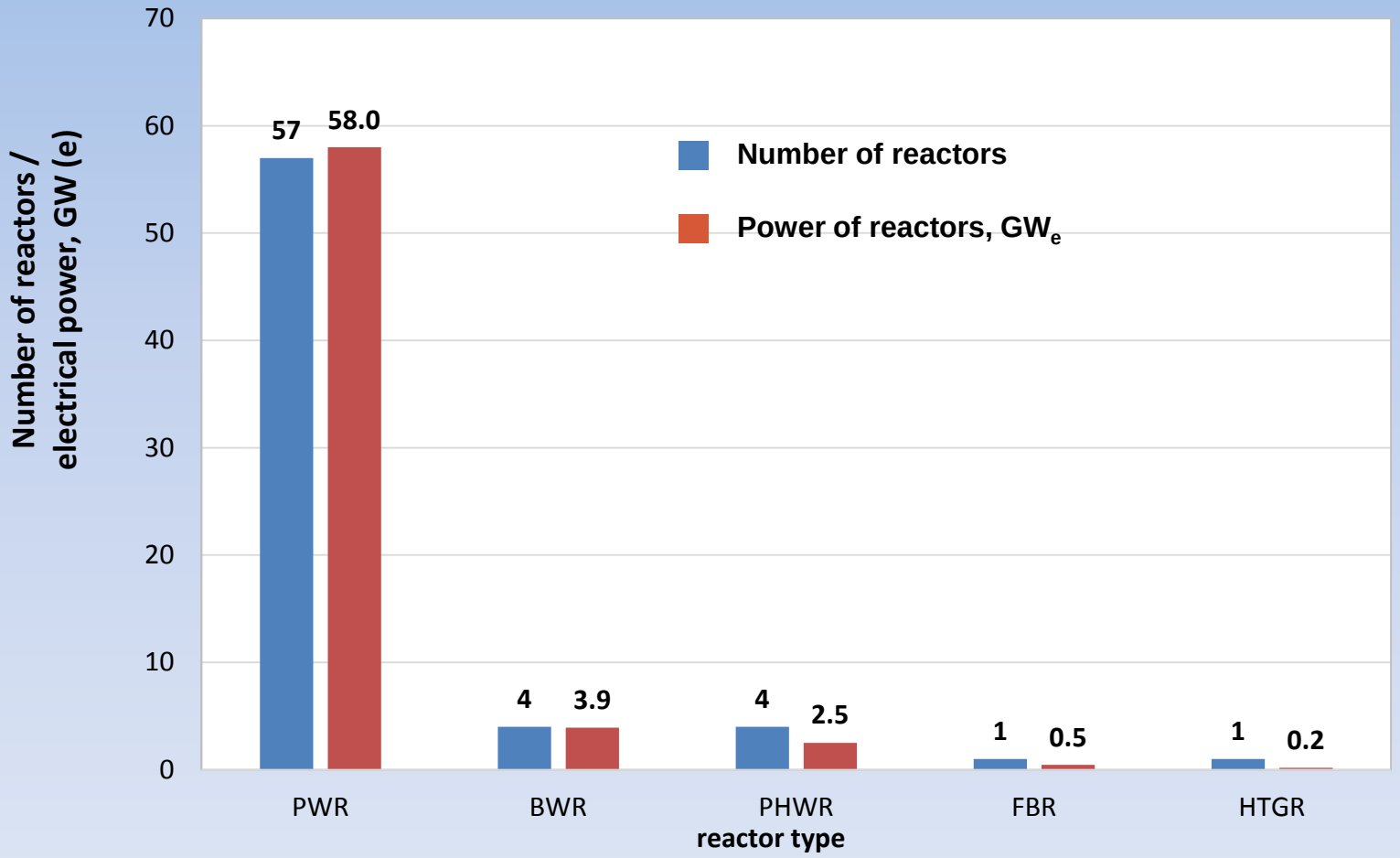
Water-moderated water-cooled pressure vessel reactors in the world

Reactor type	Number of reactors	Total power, GW_e	Share in the global reactor fleet, %	Number of countries operating the reactors
PWR	227	222.6	58	17
BWR	78	75.2	20	10
VVER	55	41.1	11	10
Other (PHWR, GCR, RBMK, FBR)	81	68.3	11	10

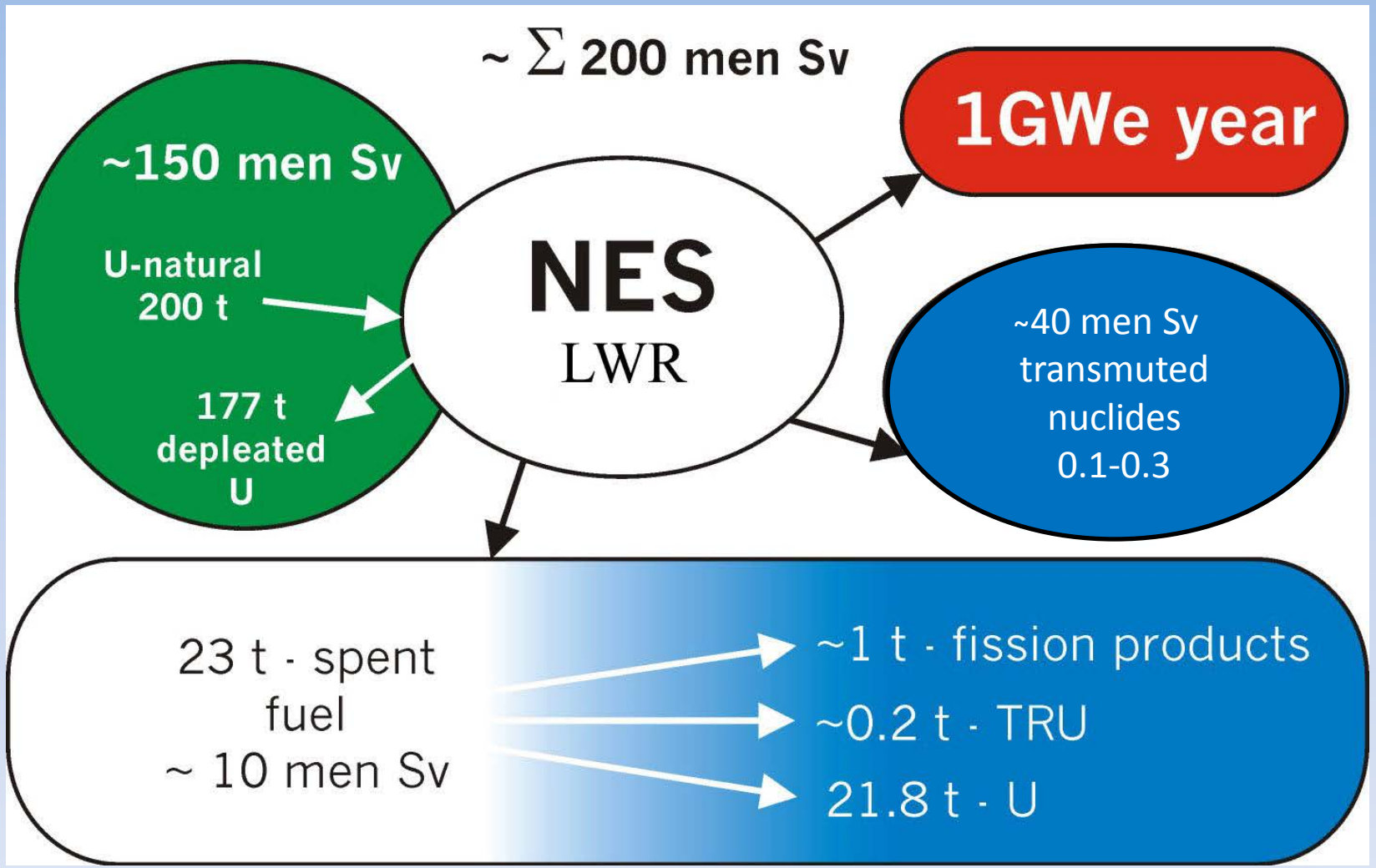

Tianwan NPP

'50 Years of Victory' icebreaker

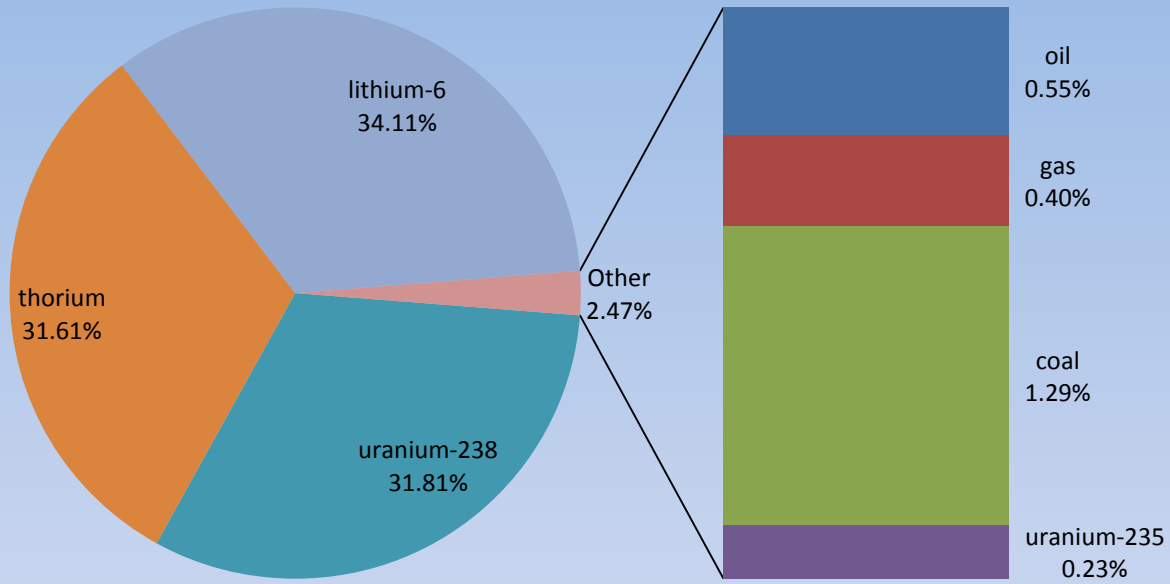
The number and power of reactors of various types being built in the world (as of the 31st of December 2015, see Nuclear Power Reactors in the World, IAEA-RDS2, 2016 Edition)



Contemporary Situation



Global distribution of energy resources, %



Assumptions used:

According to the 'Red Book', the global resources of thorium are estimated at 7 mln t; tritium is only produced from lithium-6, and the data on global resources of lithium-6 are taken according to the U.S. Geological Survey.

Global energy resources, billion TOE

oil	gas	coal	uranium-235	uranium-238	thorium	lithium-6	total
236	169	552	98	13577	13489	14555	42676

Prerequisites to defining the mission

- **The Millennium Summit (6 - 8 September 2000) Russian President Vladimir Putin: "Large-scale power industry growth on the basis of new nuclear technologies would allow saving the global fossil reserves for non-energy uses by the present and future generations, stabilizing and then diminishing the green-house effect, and providing for the ever-increasing global energy consumption in an economically and environmentally optimal way.** Any state would find it extremely difficult to attain these objectives single-handedly. We suggest that all countries concerned join their efforts in an international project under the auspices of the International Atomic Energy Agency."

- **Energy Security Summit (St.-Petersburg, 2006)** : "Those of us who have or are considering plans relating to the use and/or development of safe and secure nuclear energy believe that **its development will contribute to global energy security, while simultaneously reducing harmful air pollution and addressing the climate change challenge…** The development of innovative nuclear power systems is considered an important element for efficient and safe nuclear energy development. In this respect, we acknowledge the efforts made in the complementary frameworks of the INPRO project and the Generation IV International Forum… We reaffirm the objective to allow reliable access of all countries to nuclear energy on a competitive basis, consistent with non-proliferation commitment and standards."

Prerequisites to defining the mission

- **Jubilee session of the United National General Assembly, September 2015, Vladimir Putin:**
- …**As part of our national contribution, we plan to limit greenhouse gas emissions to 70-75 percent of the 1990 levels by the year 2030.**
- …What we need is an essentially different approach, **one that would involve introducing new, ground-breaking, nature-like technologies that would not damage the environment, but rather work in harmony with it, enabling us to restore the balance between the biosphere and technology upset by human activities.**
- …We need to join our efforts, primarily engaging countries that possess strong research and development capabilities, and have made significant advances in fundamental research. **We propose convening a special forum under the auspices of the UN to comprehensively address issues related to the depletion of natural resources habitat destruction, and climate change.** Russia is willing to co-sponsor such a forum."

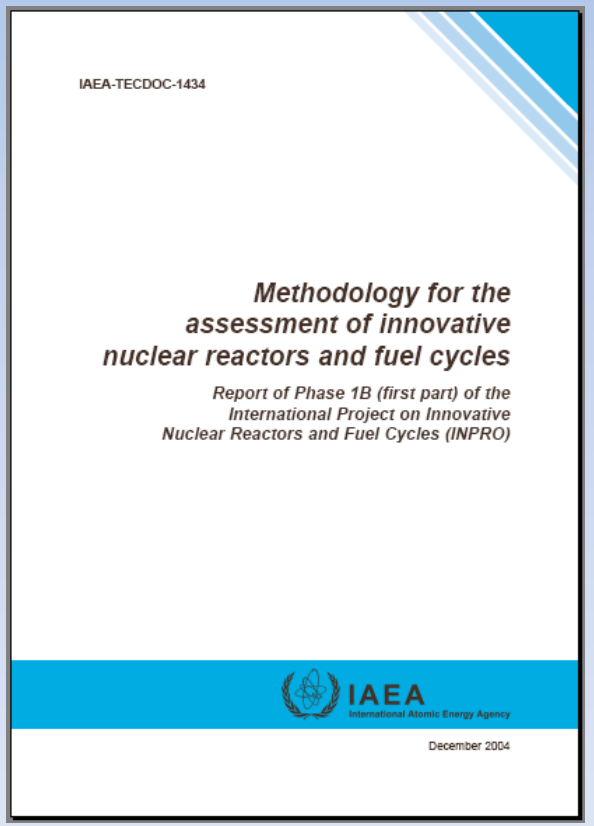
IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO Project)

INPRO methodology is a tool that can be used for:

- Analysis of the innovative nuclear energy system (INES) to define its capability to meet sustainable development requirements;
- Comparison of various INES to find preferable or optimal INES meeting the country's demands;
- Identification of R&D and demonstration systems needed to improve the existing systems and to develop missing new components of INES.

The assessment shall cover all INES components to achieve a holistic view and ensure that the overall system is sustainable.

INPRO methodology
IAEA-TECDOC-1434



Two main areas of INPRO's activities for the future nuclear power:

1-Development of requirements to the future nuclear power, NPP, NFC and necessary infrastructure;

2-Identification of types and characteristics of nuclear reactor and fuel cycle technologies that would meet the requirements.

Basic groups of INPRO requirements:

- Sustainability.
- Economy.
- Wastes.
- Safety.
- Environment.
- Non-proliferation.
- Infrastructure.

Potential of nuclear power as the basis for sustainable development

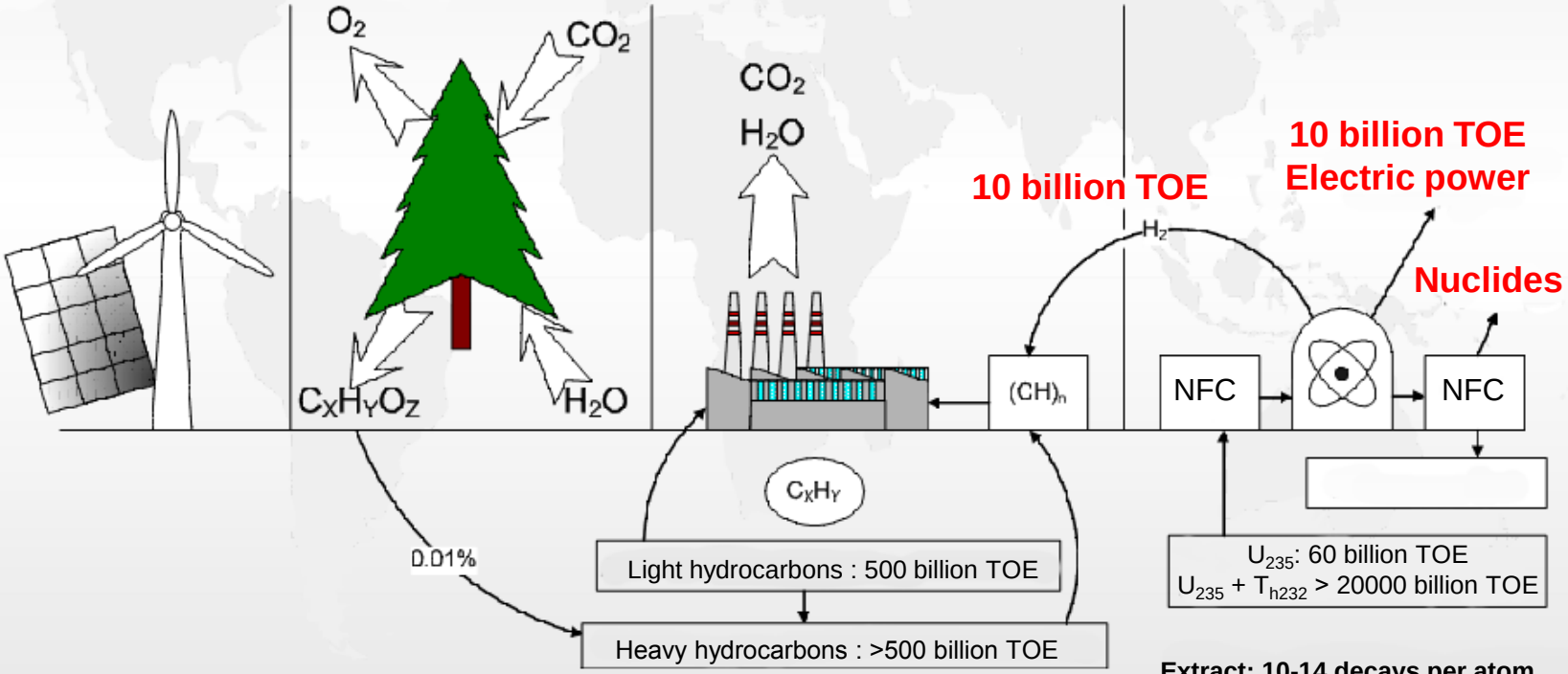
10^5 billion TOE

Renewables
2 billion TOE

Photosynthesis
100 billion TOE

Fossil-fueled power
10 billion TOE

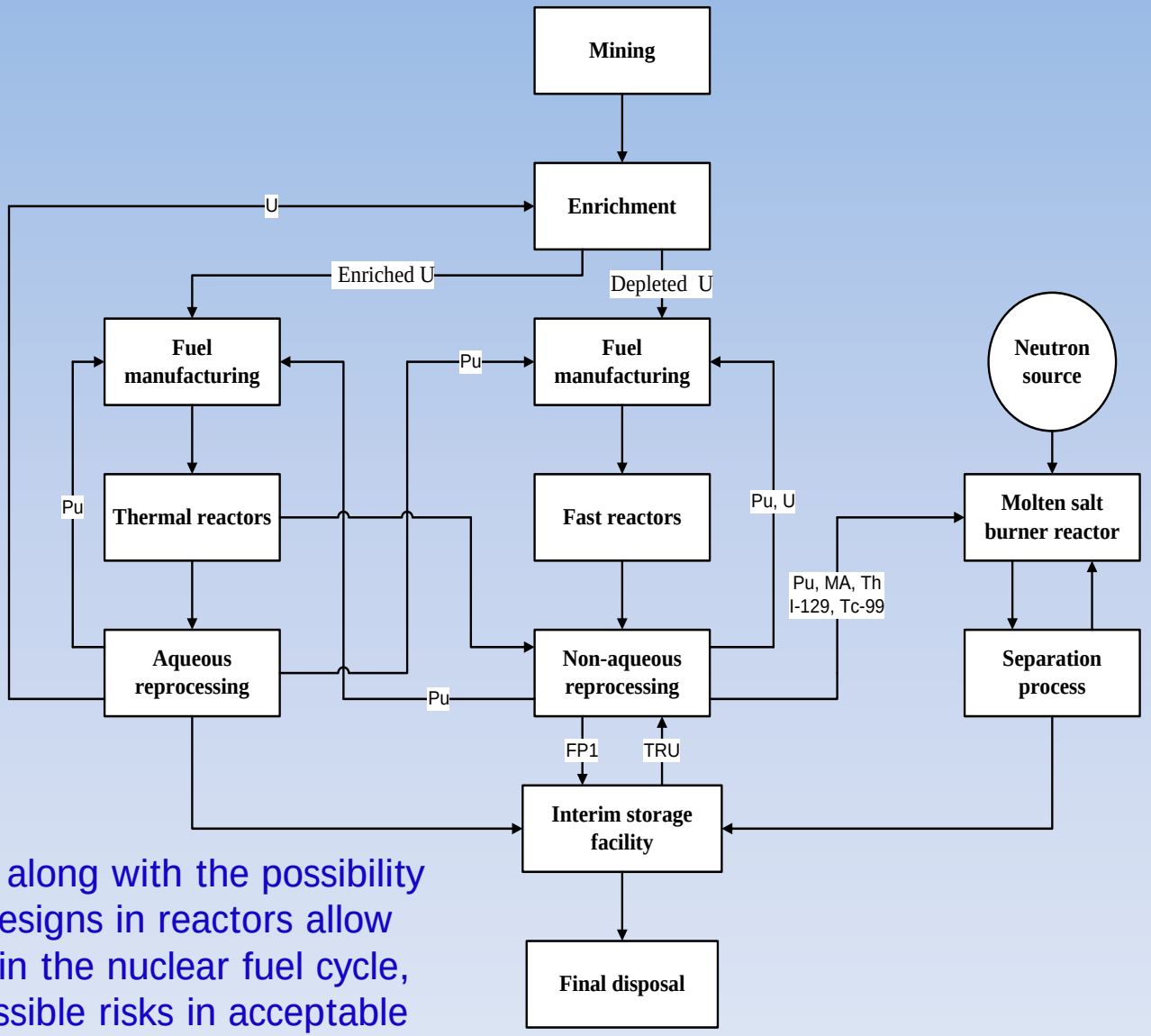
Nuclear power



Extract: 10-14 decays per atom
Dispose of: 0.2 decays per extracted atom

Multicomponent nuclear energy system with a closed fuel cycle for all actinides

The central strategic task of developing nuclear power in the Russian Federation is to implement the closed fuel cycle in order to solve the problem of spent fuel accumulation and make maximum use of the resource potential of uranium-238 and thorium-232 on the basis of thermal and fast reactors.

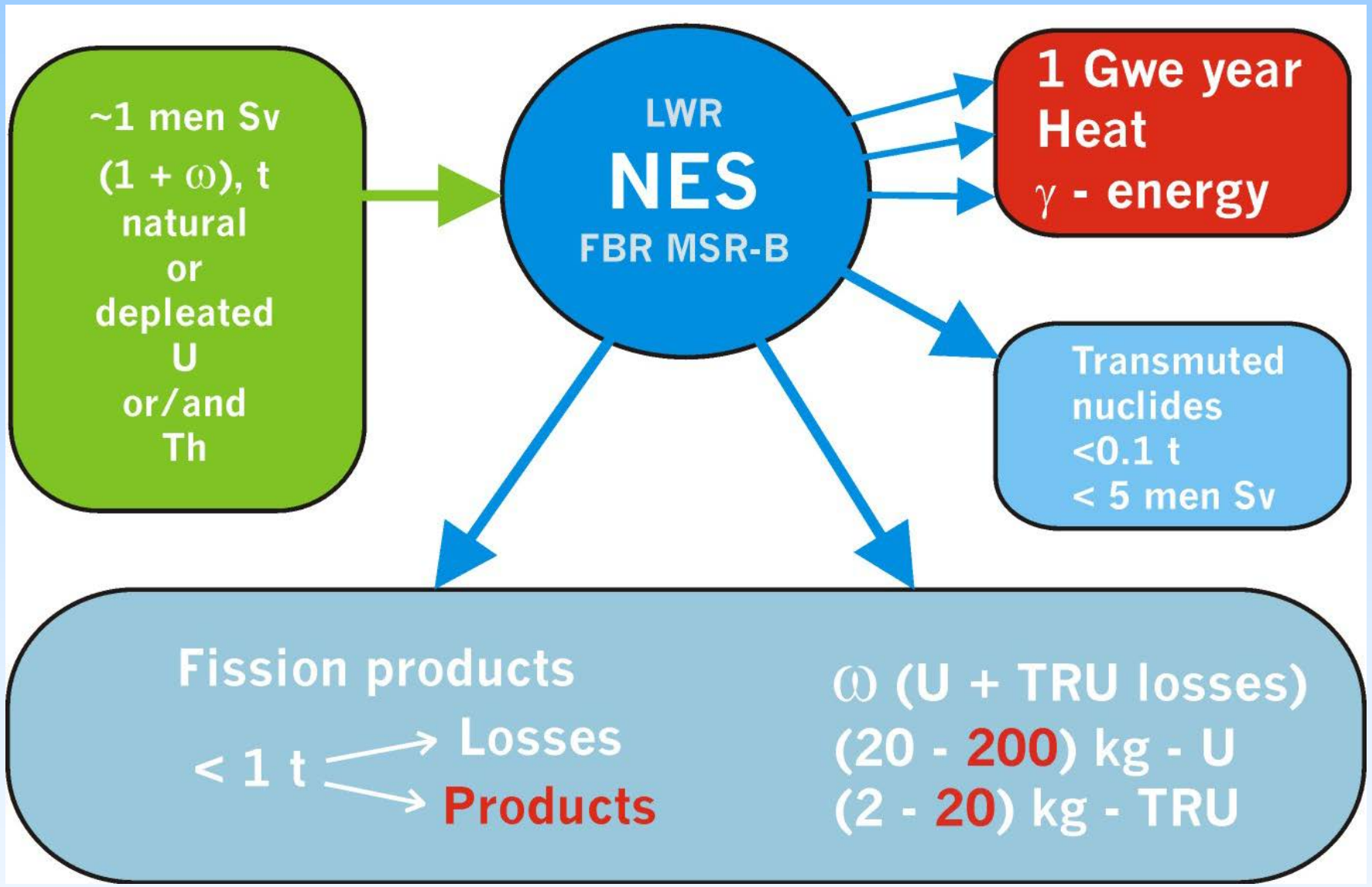


The multicomponent structure along with the possibility of implementing various fuel designs in reactors allow much room for maneuver within the nuclear fuel cycle, which may compensate for possible risks in acceptable time frames.

Structure of innovative nuclear power technologies

- New types of thermal reactors covering a wide power range with a flexible fuel cycle for various consumers
- Fast reactors for basic power generation, fuel breeding (Pu, uranium 233), and closure of the fuel cycle for U and Pu
- Molten salt reactors for closure of the fuel cycle for minor actinides
- ‘Fusion-fission’ hybrid systems for increasing the rate of involvement of uranium 238 and thorium 232 in the fuel cycle and transmuting minor actinides

Perspective balance ≤ 10men Sv



Conclusions

- Nuclear energy is valuable since it can essentially expand the range of energy sources available on Earth and ensure sustainable development of the global energy and thus of the economy. Only nuclear energy allows breeding fuel, being an energy resource capable of meeting demands of the population for hundreds or even thousands years in the future, while all the other power generation technologies based on coal, oil and gas only spend energy materials. Like renewables, nuclear energy almost does not produce green-house gas emissions when generating power.
- Global energy security is ensured through development of nuclear energy. A distinguishing feature of the nuclear energy system is that nuclear fuel cycle enterprises are also considered. The nuclear fuel cycle becomes a backbone factor for the nuclear energy.
- The thorium fuel cycle is of interest for the existing and future thermal reactors.
- Risks associated with the expected collective dose when mining thorium are at least two orders of magnitude below those for uranium mining due to the essentially shorter lived radon.
- The use of thorium reduces production of minor actinides, such as plutonium, neptunium, americium, curium..., which were not naturally abundant in the past, by orders of magnitude.
- Production of uranium 233 in fusion hybrid systems with a thorium molten-salt blanket involves essentially less radioactivity than plutonium production in thermal and fast reactors.

Thank you for attention!