ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

TWO-COMPONENT NUCLEAR POWER AND ROLE OF THERMAL AND FAST NEUTRON REACTORS

D.A.Klinov, A.V.Gulievich (JSC «SSC RF-IPPE»)

M.V.Bakanov, V.M.Troyanov (JSC «Rosenergoatom» Concern)

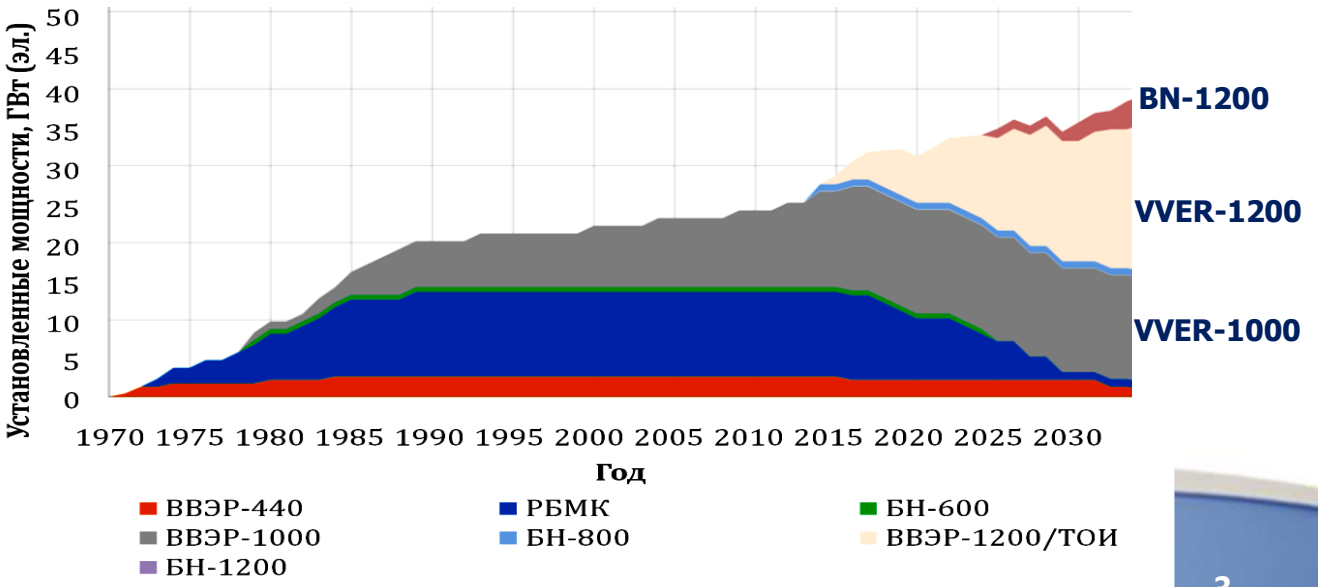
MNTK-2018
VNIIAES, 23-24 May 2018

- **It is stated in the decision given by the Rosatom Science and Technology Council Presidium that «nuclear power of the future will be a two-component nuclear energy system based on the closed NFC with thermal and fast neutron reactors».**

- **Successful operation of Beloyarsk Power Unit №3 with the BN-600 reactor for 38 years and start of commercial operation of Power Unit №4 with the BN-800 reactor play a big part in taking such a policy decision.**

NP IN RUSSIA: FACTUAL DATA AND PROSPECTS TILL 2035

- **37** NPP units with installed capacity -**30,1** GW , of which **17,7** GW - VVER, **11** GW - RBMK, **1,4** GW – BN.
- 6 power units are currently being built in Russia
- **Russian energy strategy up to 2035 and RF geographical power distribution planning scheme require:**
- Keeping the 18% share of nuclear power generation;
- Growth of aggregate installed capacity up to ~**38** GW(e) by 2035
- Taking into account the shutdown of operating RBMK power units, VVER power generation share will be about 95% by 2035.
- **Precondition of the strategy goal achievement – improvement of economic competitiveness and investment attraction of nuclear power industry**



РОСЭНЕРГОАТОМ
ЭЛЕКТРОЭНЕРГЕТИЧЕСКИЙ ДИВИЗИОН РОСАТОМА

RUSSIA'S INTERNATIONAL COMMITMENTS

The programme of building NPPs abroad. Rosatom's portfolio of foreign orders contains 33 units.

Export of nuclear fuel (17% of the world market belongs to Russia) and services in the field of enriching natural uranium, geological exploration and uranium mining abroad, creation of nuclear research centres in different countries, etc.

ONE-COMPONENT NUCLEAR POWER

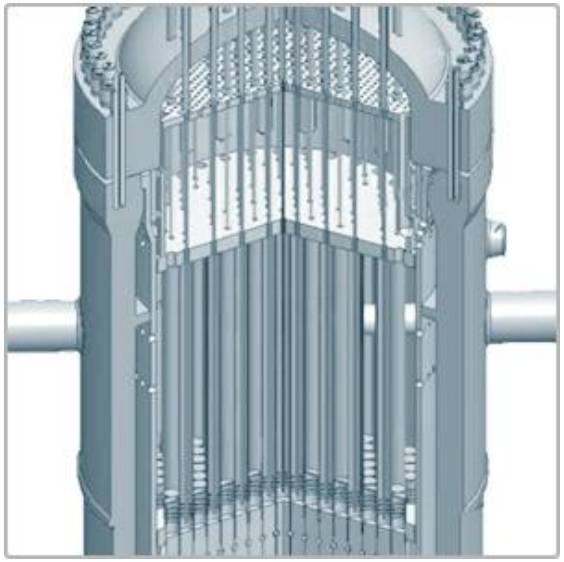
The only function of thermal reactors in today's (one-component) nuclear power is to produce electricity, they are almost completely «separated» from fuel fabrication, which takes place at the mines and mining processing plants of ARMZ Uranium Holding Co and TVEL Fuel Co, by using natural uranium.

- Comparatively cheap (not higher than 130$ per kilo) uranium resources in Russia are estimated at 600 – 700 thousand tonnes according to different sources.
- So far 290 thousand tonnes of SNF have been produced worldwide, 90 thousand tonnes have been reprocessed and about 10 thousand tonnes of SNF* are unloaded from reactors every year
- Over 24 thousand tonnes of SNF have been accumulated in Russia so far, 650 tonnes* added to it each next year

*D.N.Kolupaev. Development of SNF waste processing technologies in Russia. 10.11.2015, Moscow, «Atomeco-2015»

IMPROVEMENT OF VVER TECHNOLOGIES

1. Improvement of the existing projects: VVER-1200, VVER-TOI
2. Development and construction of advanced NPPs: Super-VVER, SCWR, low- and medium-energy VVER
3. Improvement of NFC technologies (REMIX, MOX).



TWO-COMPONENT NP

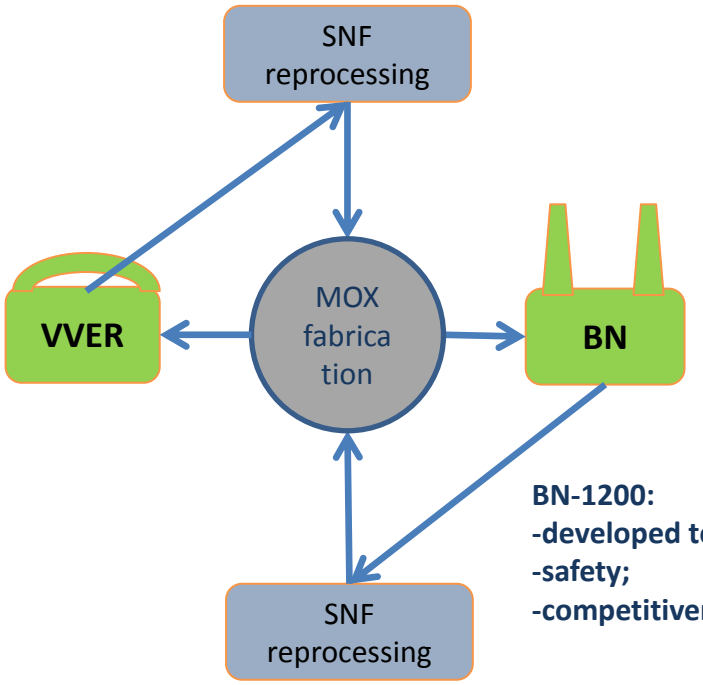
(Rosenergoatom, IPPE, KI, OKBM)

Nuclear power, whose components play different functional roles in the energy system consisting of fast and thermal reactors that work synergistically in a single closed nuclear fuel cycle, which has fuel resources for development (BR of the system >1).

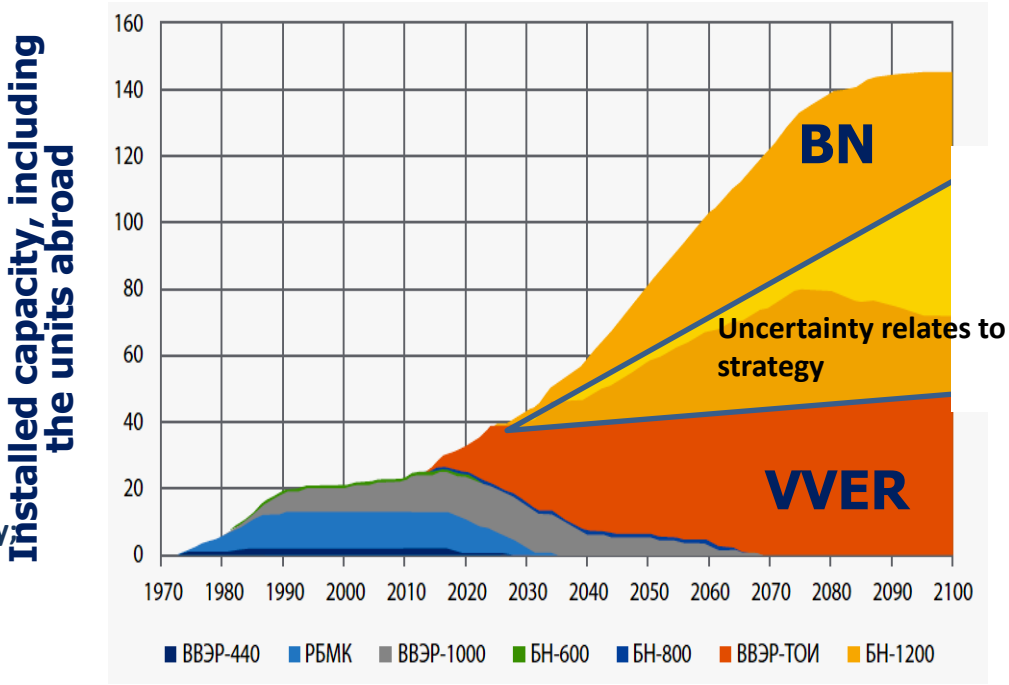
- **Thermal reactors with low BR produce «cheap» electricity.**
- **Fast reactors with BR>1 provide the fuel source, use SNF from VVERs and BNs, burn MA for the whole system.**

CONCERN'S VIEWPOINT: CHANGEOVER TO TWO-COMPONENT NUCLEAR ENERGY SYSTEM

The proportion of fast to thermal reactor facilities in a two-component system depends on the implemented strategy: from using plutonium and MA of VVER SNF to totally supplying all VVERs (including those abroad) with plutonium.



BN-1200:
-developed technology;
-safety;
-competitiveness

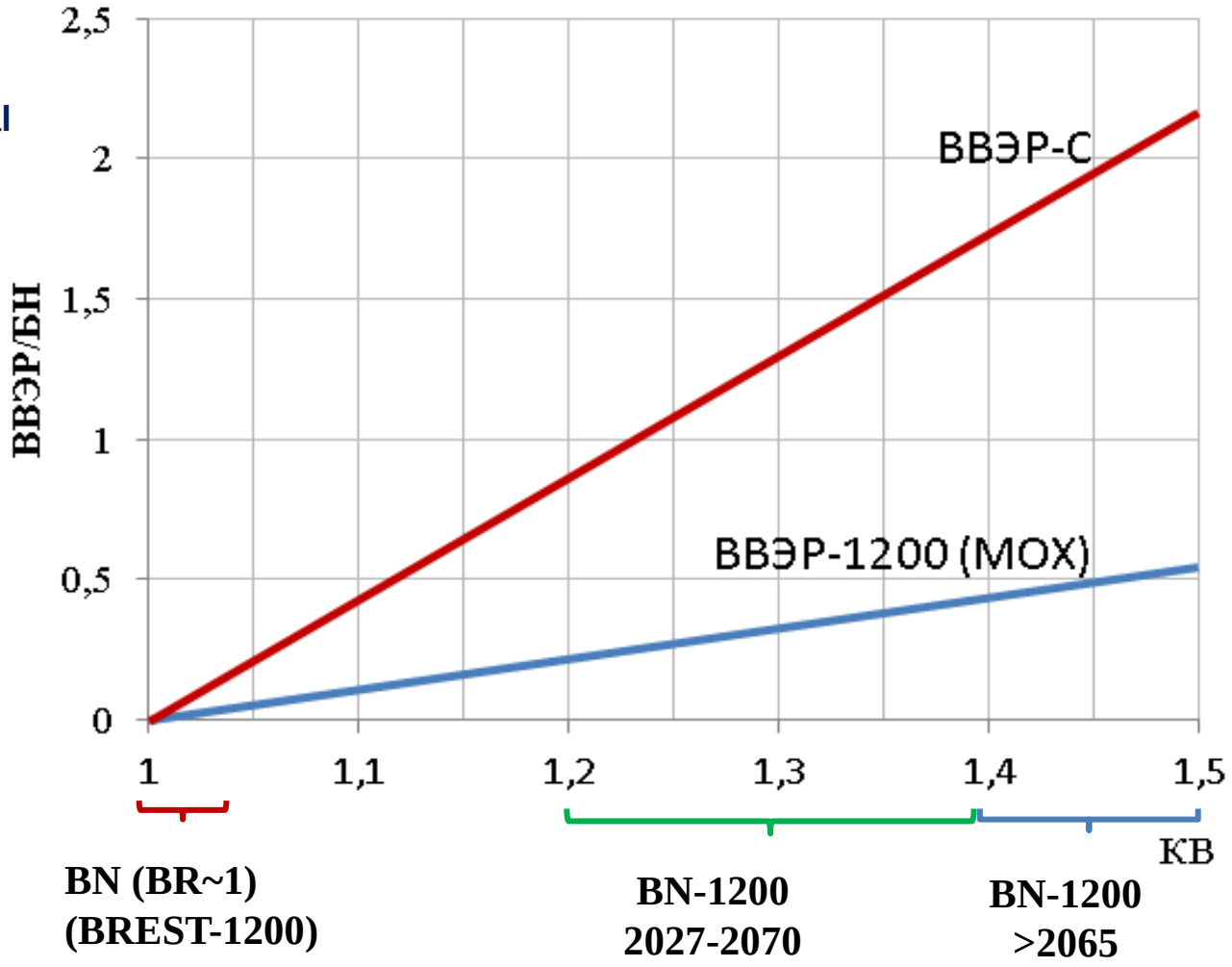


РОСЭНЕРГОАТОМ
ЭЛЕКТРОЭНЕРГЕТИЧЕСКИЙ ДИВИЗИОН РОСАТОМА

The ratio of VVER-TOI (MOX), VVER-S to BN (BREST) for the stationary case of NP with different CRs

The proportion of thermal to fast reactors in NES depends on :

- **Parameters of thermal and fast reactors;**
- **NP development scenario – growth, stagnation or termination;**
- **Inventory of external plutonium or SNF;**
- **Export commitments;**
- **Temporary delays in FC, etc.**



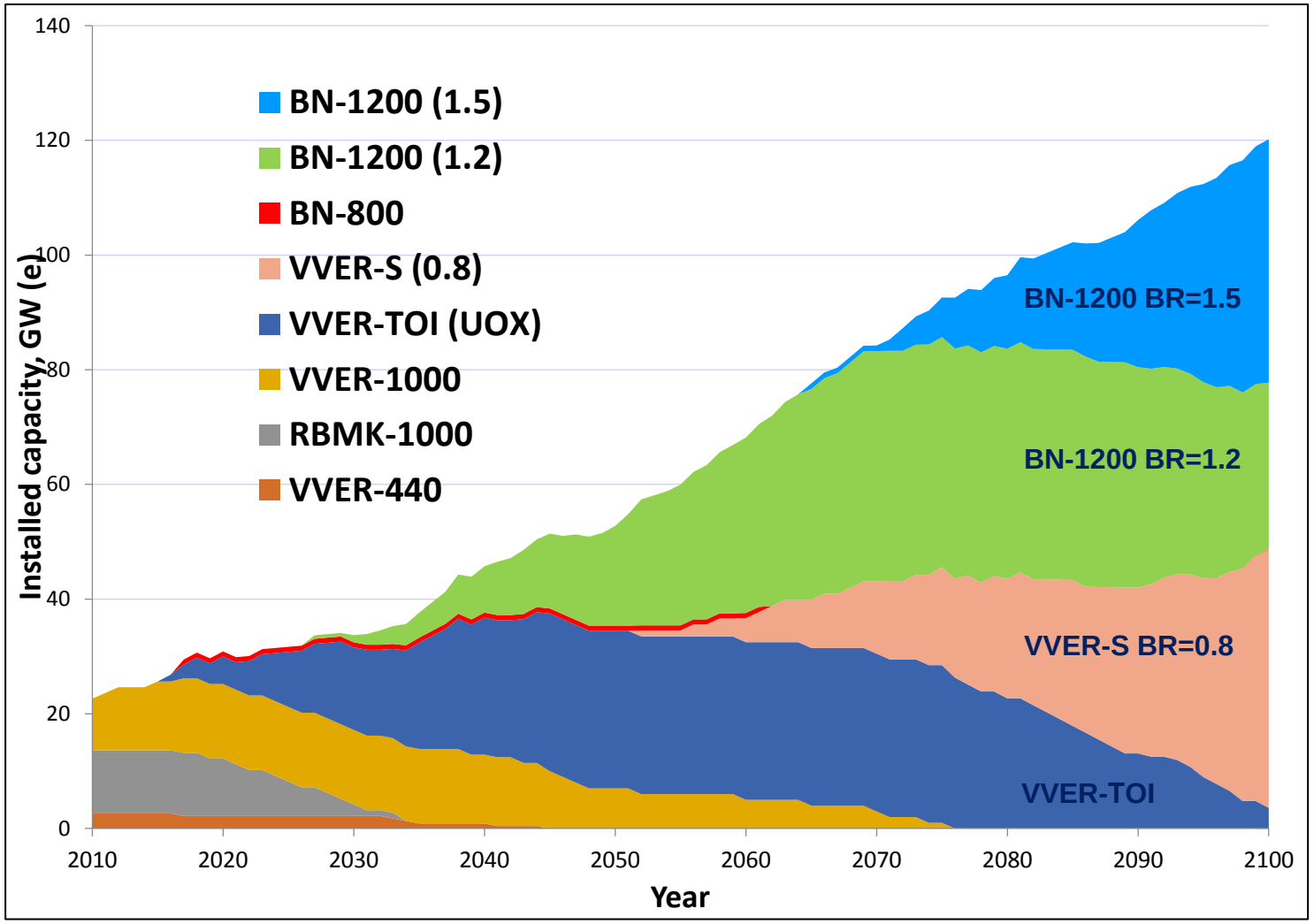
BN (MOX) – VVER (UOX and MOX)

- Synergy of two components
- Common fuel cycle (UOX and MOX)

→ **there is no goal of replacing thermal reactors with fast ones at an accelerated speed!**

- There is an option of using plutonium from VVER SNF in BNs (no restrictions on Pu isotopic composition)
- Possibility of the replenishment supply of thermal reactors with MOX fuel produced from BN SNF (when demonstrating commercial effectiveness)
- Expansion of VVER export potential as regards SNF reception and fuel supply.
- Stricter workable non-proliferation regime as it is fuel services rather than reactor and radiochemical technologies that are exported.
- Maintenance during the whole nuclear power plant life, including units abroad.
- No risk in commissioning a small/ large series of BNs as there will be demand for them whatever scenario of NP development after 2050 unfolds!

Development scenario of two-component NP, using nuclear reactors with improved fuel characteristics



TWO-COMPONENT NP

(Innovation and Technology Center by “PRORYV” Project)

Nuclear power consisting of independent components competing for uranium resources, i.e. fast reactors with so called «native» safety (CR~1) and thermal reactors. With such NP, each fast reactor has its own closed cycle whereas thermal reactors operate in centralized, open NFC.

Forced requirement – to stop building VVERs after 2040 and replace them with FRs at an accelerated speed.

Necessary prerequisite – economic and technical feasibility of technology for FR with «native» safety. They have to be «cheaper» than VVERs!

FR (Mixed Nitride U-Pu) – VVER (UOX)

Competitive coexistence of two components	→	Two different fuel cycles (UOX and MNU-Pu)
Rushed replacement of thermal reactors with FRs featuring «native» safety	→	Necessity to commission a FR using enriched uranium
1$ restriction on the reactivity margin, especially during the start-up and transient reactor period	→	Facing performance problems when Pu from FR SNF is used (CCR, MA, change of the core geometry, etc.)
Restriction on breeding ratio for FR (BR~1.05)	→	Impossibility of using Pu from FR SNF for fuel supply of thermal reactors and commissioning of new FRs
Limit to the system development – exhaustion of natural uranium	→	FRs with «natural» safety don't allow for fuel breeding
Export of reactor and radiochemical technologies (in the form of collocated NFC)	→	- Significantly relaxed non-proliferation regime - No maintenance during the plant life of the units abroad

Updating/ change of the «native» safety requirements is necessary as regards sodium reactors with BR>1

Two (three-) component NP

NP comprising fast reactors with different conversion ratios, where BNs provide resources for the system development (BR>1) and FRs with «native» safety (BR~1) produce «cheap» electricity. Fuel is mixed nitride U-Pu, metal…

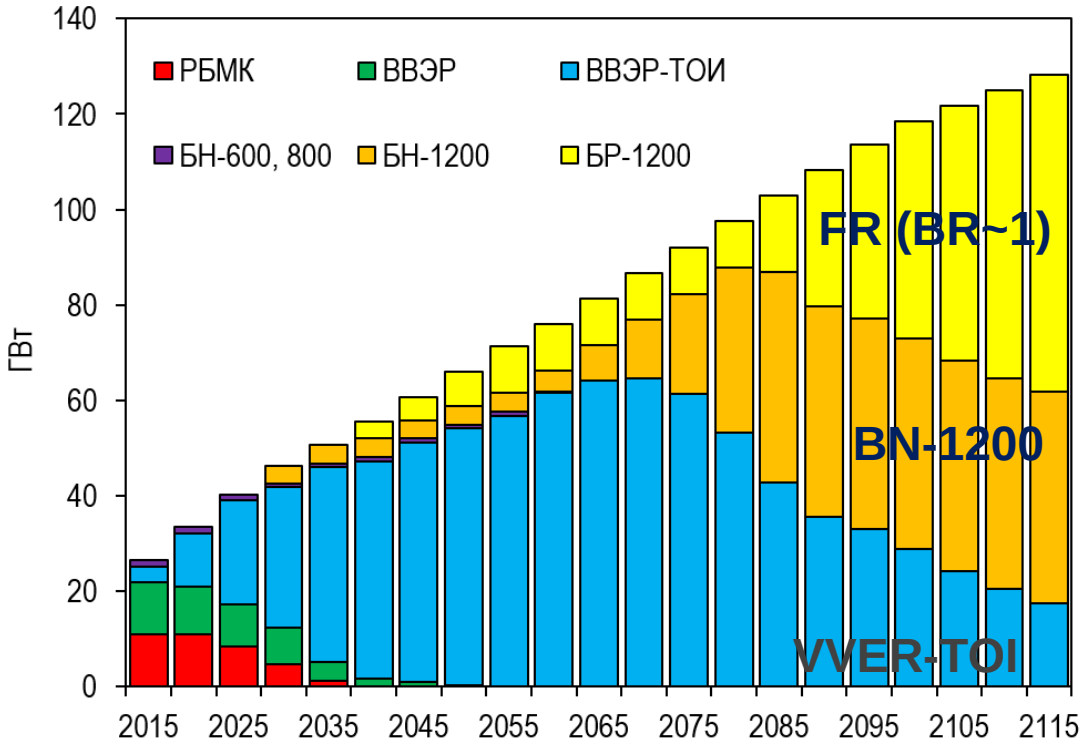
In a system like that, FRs will «play» the part of replaced VVERs which can also function as the «third» component.

It is important to consider possible emergence of reactors operating for nuclear hydrogen power.

FR (Mixed Nitride U-Pu) – BN (MNU-Pu/MOX)

Two-component system consisting of BNs (BR>1) and FRs (BR~1) is only possible if FRs show higher commercial effectiveness and safety than VVERs.

However, FRs with «native» safety can't replace BNs which solely provide development for the two-component system.

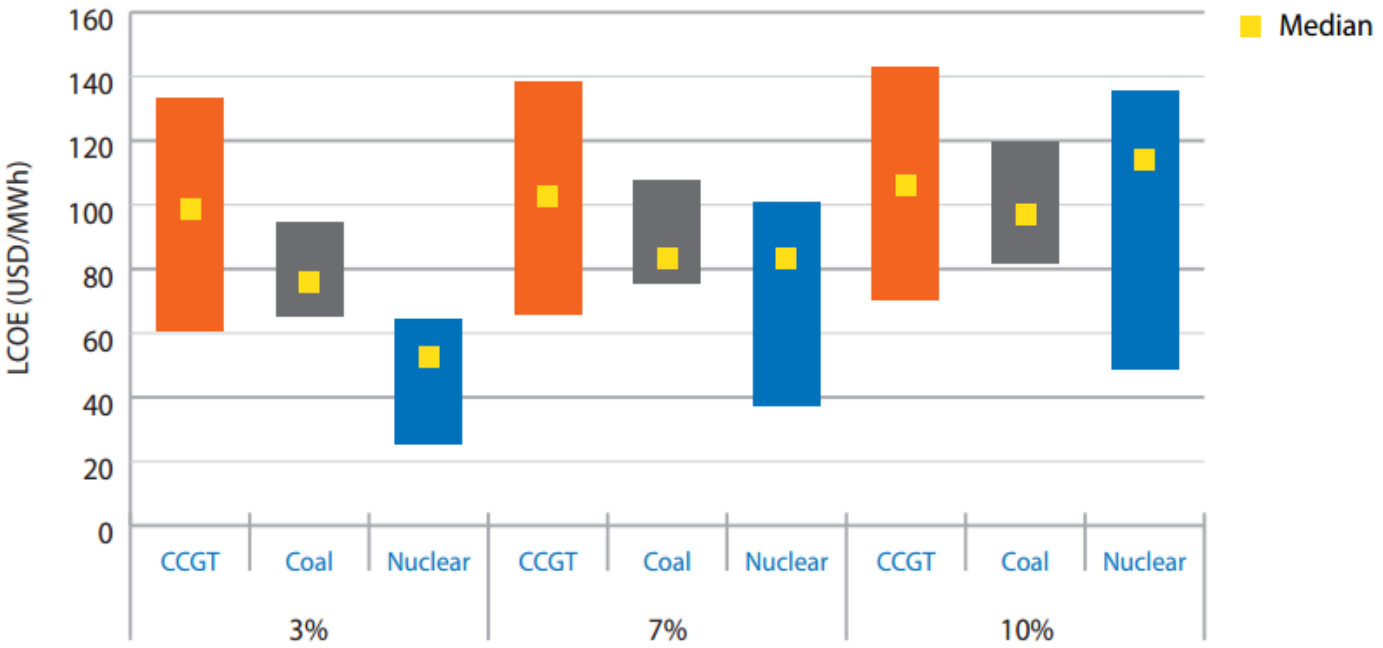


Conclusion: the BN fuel supply component is not auxiliary, it is basic!

A.A.Andrianov et al. Optimization models of two-component nuclear power based on closed NFC with thermal and fast reactors.

LCOE ranges for baseload technologies
(at each discount rate) (*)

Figure ES.1: LCOE ranges for baseload technologies (at each discount rate)



The ranges presented include results from all countries analysed in this study, and therefore obscure regional variations. For a more granular analysis, see Chapter 3 on "Technology overview".

(*) Projected Costs of Generating Electricity 2015 Edition.
INTERNATIONAL ENERGY AGENCY NUCLEAR ENERGY AGENCY ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
Organisation for Economic Co-operation and Development/Nuclear Energy Agency

CRITERIA FOR CHOOSING THE NP DEVELOPMENT OPTION

The LCOE criterion is deficient because of its considerable uncertainty for developed technologies and because it doesn't take into account the degree of effectiveness of solutions to NP systemic problems in the field of safety, SNF and radioactive waste, natural uranium efficiency, non-proliferation.

Taking into account the global nature of NP systemic problems (namely in the field of safety, non-proliferation) and orientation towards expanding the export potential of Russian nuclear technologies and services, it is necessary to adopt international approaches and use of multicriterion analysis when choosing the NP development option.

Example of Efficiency Evaluation of a VVER System and a Two-Component NES (BN + VVER)

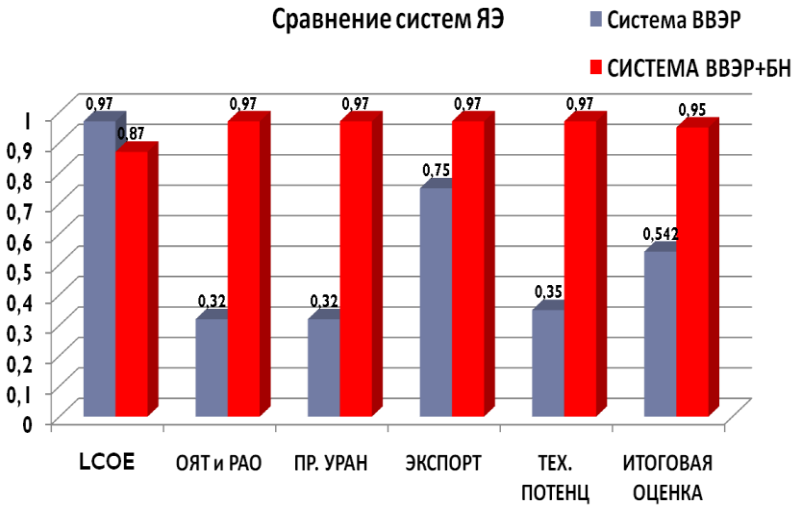
- **Scenario 1**

  Only TRs that operate in an open fuel cycle with a deferred disposal solution (SNF accumulation)

- **Scenario 2**

  Commissioning of 3 BN-1200 before 2035 and VVER-1200 / TOI reactors before 2035 is envisaged, followed by subsequent commissioning of 15 BN-1200 more before 2050.

  Both scenarios coincide in power distribution over years.



Key indicators:

LCOE – economy;
SNF and RW management;
Natural uranium consumption;
Export potential;
Technological potential.

Conclusions

- **Rosatom's Science and Technology Council Presidium determined creation of a two-component nuclear energy system based on the closed NFC with thermal and fast neutron reactors as a strategy goal. However, neither ideological nor technological foundation for creation of the two-component NES has been adopted yet. Comprehensive assessment is to be carried out and reasonable choice is to be made from suggestions offered by the supporters of two fast reactor technological directions.**

- **For the development of the NES second component – VVERs – there is only a short-term certainty that exists as long as technical characteristics of VVER-TOI reactors are quite clear. Further development of VVER technologies is mentioned in the conceptual provisions of the Strategy but its design and technology study is not sufficient.**

Conclusions

- **System studies are of highest importance for formulating the technological strategy of NP development, they are to help decide on the optimal strategy option in the end.**

- **«Native» safety requirements to BN-1200 sodium fast reactors should be updated/ changed in accordance with their functional roles in the two-component system.**

- **It is necessary to take a decision about construction of BN-1200 one-of-a-kind unit as the basis of the future fuel supply component in Russia's NP. Decision on whether to build the BN-1200 one-of-a-kind unit or not according only to the LCOE criterion is faulty! Such a decision should be made on the basis of multi-criterion analysis taking into account the two-component NP system, with regard to its future development after 2050.**

Thank you for attention!