ATOMEXPO 2017

Round table: Innovative engineering solutions in the history of nuclear industry as a prerequisite of sustainable development

Perspectives of development of two-component nuclear energy system – vision of Russian customer

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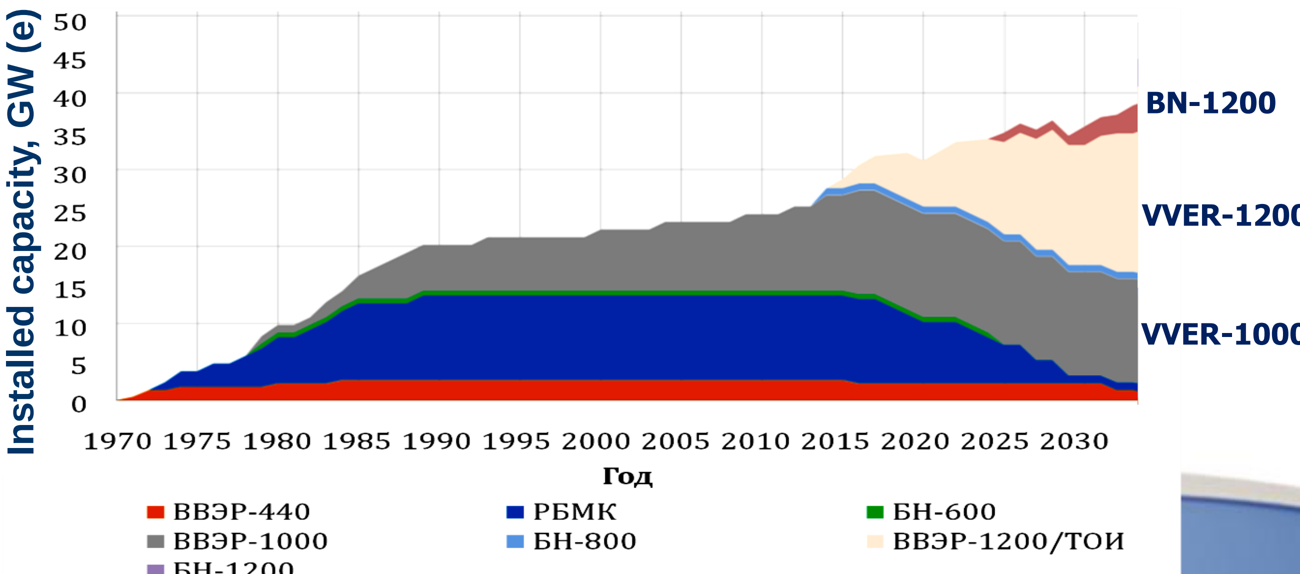
Russian nuclear power: actuals and prospective up to 2035

- 35 nuclear power units with installed capacity 27.9 GW, of which 15.5 GW - VVER, 11 GW - RBMK, and 1.4 GW – BN reactors.

- **The Russian Energy Strategy up to 2035 and the RF Territorial Power Generation Planning Scheme prescribe:**
- Keeping the share of nuclear power generation up to 18%;
- Growth of total installed capacity up to ~38 GW(e) by 2035
- With phasing-out of existing RBMK power units, VVER power generation share will make about 95% by 2035.

- **Precondition of the Strategy goal achievement is improvement of economic competitiveness and investment attractiveness of nuclear power industry**

Structure of Russian nuclear energy system till 2035



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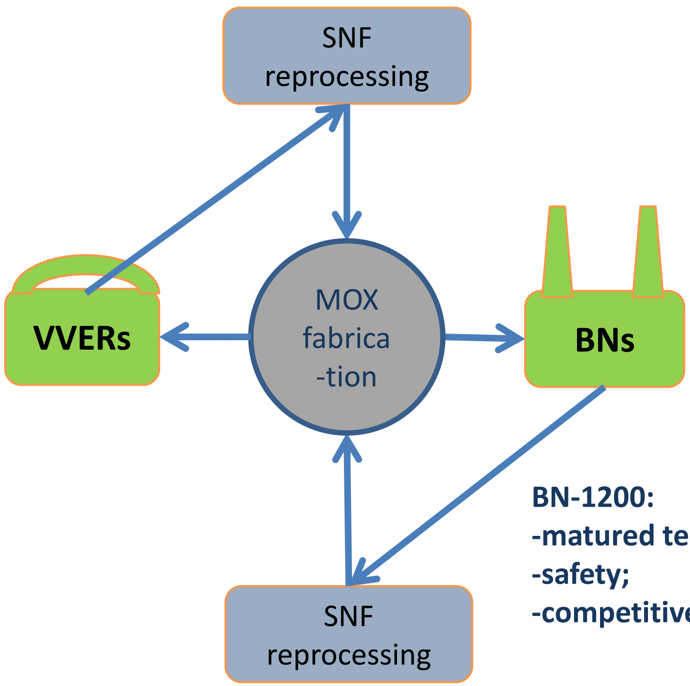
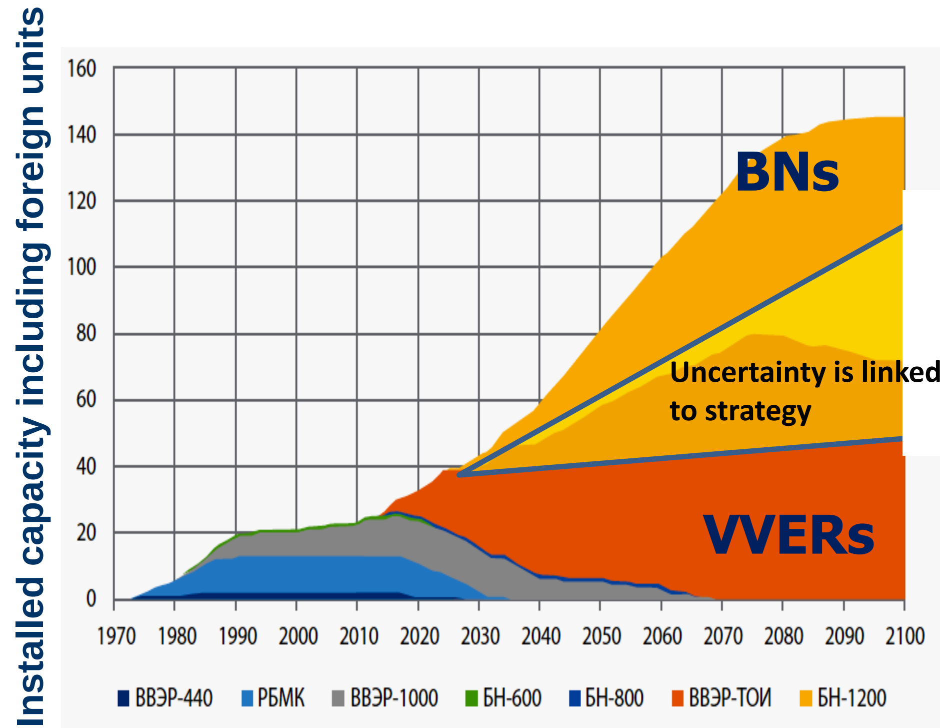
Rosenergoatom strategy: transfer to a two-component nuclear energy system

Balance between fast and thermal neutron reactor units in a two-component system depends on the strategy being implemented: from utilization of plutonium and minor actinides (MA) from VVER SNF to a complete meeting of plutonium demands of VVERs (including foreign power units).



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



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Advantages of two-component nuclear energy system (NES)

NES shall ensure economic efficiency of nuclear generation at the domestic market due to:

1) use of unlimited resource of waste uranium and natural uranium for feeding-up the fuel cycle of BN and VVER reactors having in mind inevitable shortage of uranium and its price growth;
2) liquidation of accumulated plutonium stocks;
3) reduction of accumulated SNF volumes through its reprocessing and nuclear materials recycling – resulting in reduction of Rosenergoatom expenditures for SNF management;
4) considerable reduction of RW activity and volume due to long-living RW (minor actinides) burning-up in BN reactors;
5) plutonium production in BN reactors and its utilization in VVER reactors as MOX fuel .

NES will open new opportunities for the State Corporation Rosatom at the external markets due to:

6) VVER export along with nuclear fuel "leasing";
7) commercial and scientific & technical cooperation in the field of BN technologies;
8) additional SNF related services for foreign NPPs as regard to storing, reprocessing and recycling of the extracted nuclear materials in BN reactors.

Roles in two-component nuclear energy system:

BN reactors:

•Generate electricity in the base load mode, allow for **power maneuvering within the range 100%-75%-100%.**

•Use accumulated waste uranium or regenerated uranium as a feed-up, produce plutonium in a form most suitable for MOX fuel fabrication for VVER reactors;

•Burn-up long-living highly active RW **– minor actinides,** which are extracted as part of BN and VVER SNF reprocessing;

VVER reactors:

•Generates electricity in the mode of following the grid operator requests on power maneuvering;

•Partially use **MOX fuel** instead of UO_2 fuel;

•**Exported abroad** under a condition of SNF repatriation to Russia;

•**Plutonium extracted from VVER SNF** is used for MOX fuel fabrication for BN reactors.

Nuclear fuel cycle enterprises :

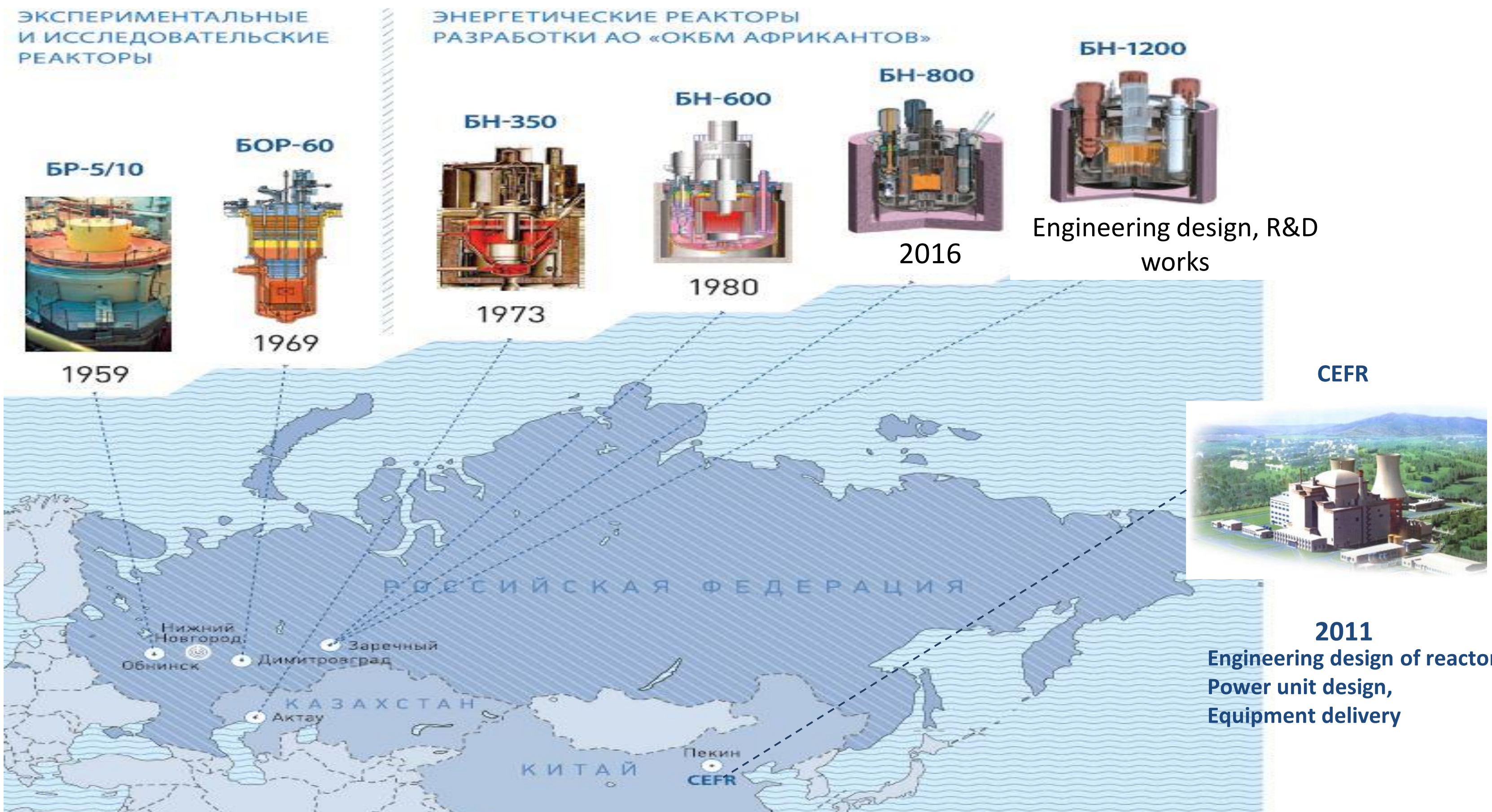
•Provide for BN and VVER SNP reprocessing and nuclear materials extraction for reuse;

•Fabricate MOX-fuel using waste uranium or regenerated uranium as well as plutonium extracted from SNF;

•Ensure RW fractioning with the goal of subsequent utilization of minor actinides and reduction of nuclear material proliferation risks, provide for RW conditioning and disposal.

Maturity of sodium cooled fast neutron reactor technology

Russian experience with BN reactor technology elaboration is over 150 reactor/years

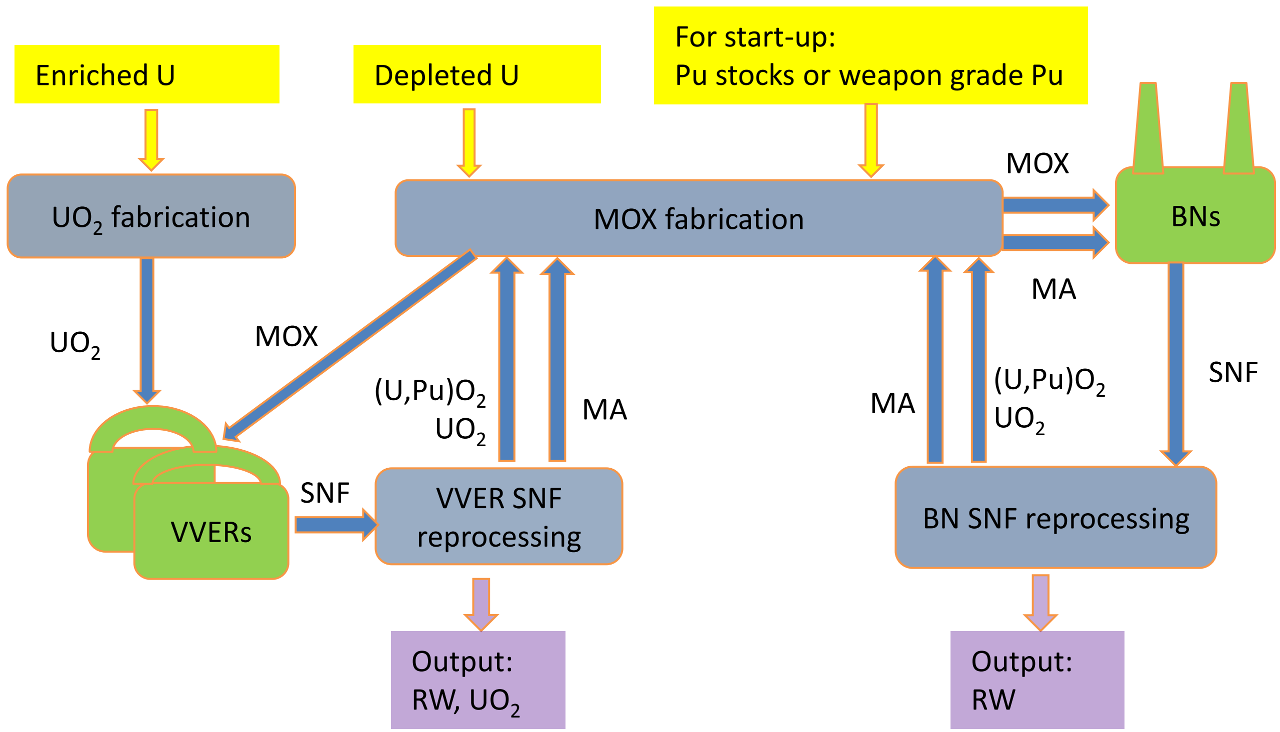


BN-1200 safety: exclusion of any need to evacuate the public in case of an emergency;
probability of severe core damage is below 10^{-6} per reactor per year;
in-vessel retention of core components damaged in a severe accident

Rosenergoatom strategy regarding fuel selection for BN reactors: MOX-fuel

1. Fuel should be highly rated as regard to operation reliability, power output and allowing its further development beyond the performance level achieved;
2. Presently, those requirements are met by uranium oxide and MOX fuels;
3. So far, results of mixed nitride U-Pu (MNUP) fuel development works do not allow us considering it be meeting the above said requirements;
4. In a two-component NES, the key task towards reducing the nuclear fuel cycle (NFC) costs is the use of a unified fuel for both NES components;
5. Burnup level currently achieved for MOX fuel is 12.6% h.a., and for MNUP fuel - 5.4% h.a.;
6. From the above one can conclude that MOX fuel is more beneficial. Nevertheless, as soon as MNUP fuel development progresses to a certain level, Rosenergoatom will be ready to use MNUP fuel.

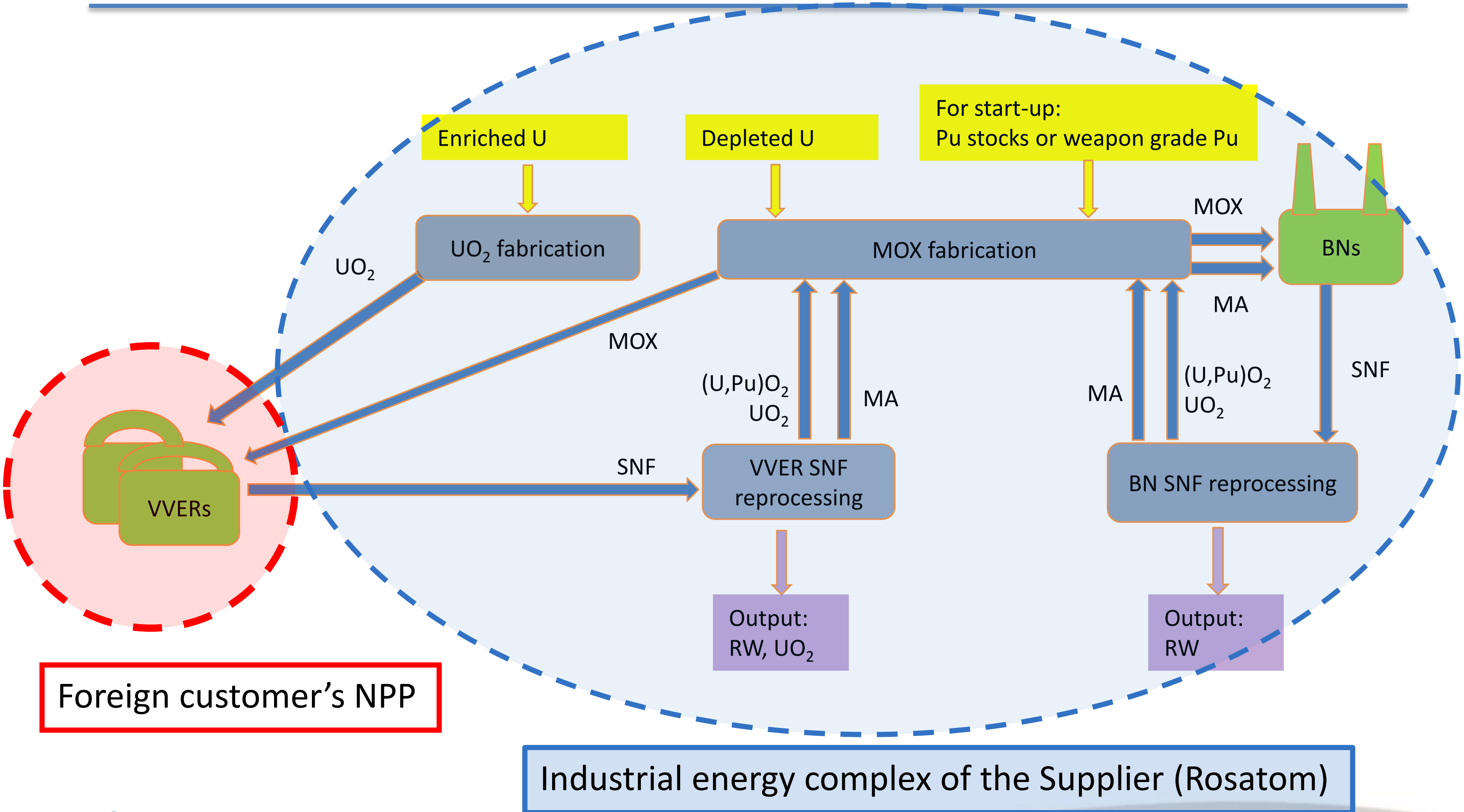
Rosenergoatom strategy on selection of NFC arrangement type: a centralized NFC



Such a centralized NFC as part of the two-component NES ensure reprocessing of SNF from both VVER and BN reactors, MOX-fuel fabrication for VVER and BN reactors, with a possibility of mutual exchange with reprocessing products.

Aggregate balance in a system comprising 1 BN + 2 VVERs: both natural uranium consumption and uranium separation work are two times less as compared to 3 VVERs

Rosenergoatom strategy for international cooperation: a centralized NFC in Russia for NPPs abroad



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Readiness to introduce NES

- **As of today, Russia is the only country having necessary technologies and sufficient operating experience with all integral parts as needed for introduction of a two-component nuclear energy system based on reactors with thermal and fast neutrons and closed nuclear fuel cycle:**
  - Experience with development and operation of thermal neutron reactors of VVER type and fast neutron reactors of BN type;
  - Industrial technologies of MOX fuel fabrication;
  - Industrial technologies for storage and reprocessing SNF from thermal and fast neutron reactors;
  - Investigations to substantiate MA burning-up and RW activity reduction.

Resulting principles of rendering services to NES consumers (1/2)

1. Avoid burdening the consumers with the problem of establishing production facilities for fresh fuel fabrication and SNF management;
2. Fuel, including MOX fuel, is to be leased during the entire life cycle;
3. Ensure consolidation and utilization in reactors, under IAEA guarantees, of substantial volumes of civil plutonium accumulated in the world;
4. Increase ecological acceptability of the nuclear option through use of modern technologies for MA burning-up and RW management;
5. Ensure minimization of national sensitive nuclear technology programmes being undertaken as part of implementation of national programmes for nuclear industry development.

Resulting principles of rendering services to NES consumers (2/2)

- **Within introduction of two-component nuclear energy system based on thermal and fast neutron reactors and closed nuclear fuel cycle, Russia is ready to expand international cooperation for:**
  - Establishing, *inter alia* with involvement of foreign investors, international centers on the base of power units with fast neutron reactor and centers of SNF reprocessing/nuclear fuel fabrication;
  - Participation in international projects focused on designing and operation of fast neutron reactors;
  - Supply of equipment and rendering consulting services for creation of modern fast neutron reactors.

Thank you for your attention!