



ROSATOM

V International School
on Power Reactors Spent Nuclear Fuel Management

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

Rosatom`s activities in the Spent Nuclear Fuel Management : status, trends, projects

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Russian Nuclear Power Plants fleet

VVER-1000/1200:

13 units in operation (12- VVER-1000, 1- VVER-1200) + 8 units under construction

18,6% of the electricity generated in the country

10 NPP

RBMK-1000: 11 units in operation

35 nuclear power units

VVER-440: 5 units in operation till 2030, 3 units are in the course of decommissioning

most of them located in the european part of the country

EGP-6: 4 units in operation, decommissioning is scheduled for 2019-2021

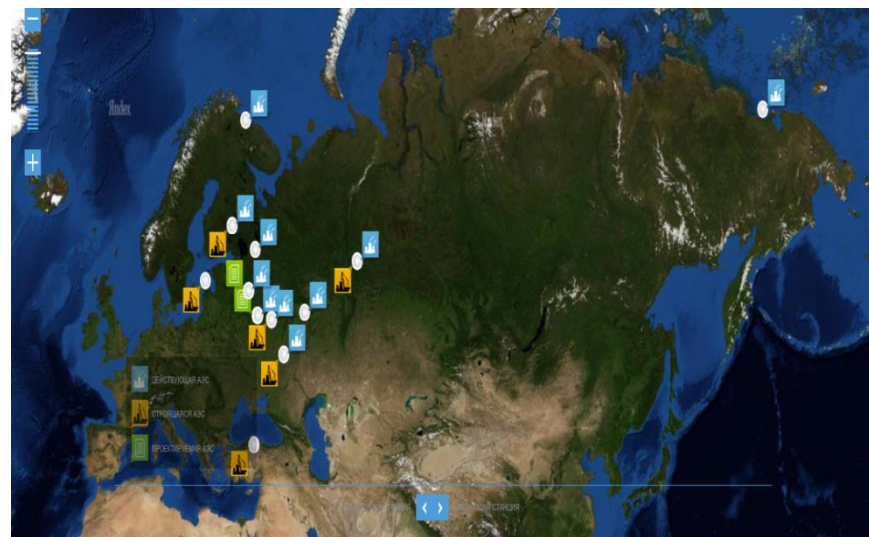
BN-600 (FR) 1 units in operation

BN-800(FR) 1 unit in operation

Research reactors

Ice-breakers

Submarines

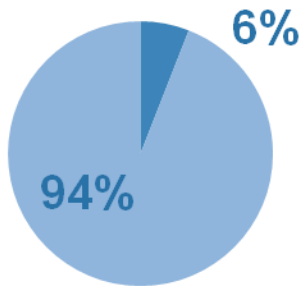


Annual accumulation UF amounts about 700 tons, up to 230 tons/year reprocessed

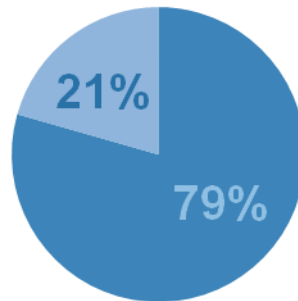
Peculiarity of Russian Practice in SNF Management

Residual operational lifetime of NPPs by sectors (reactor/year)

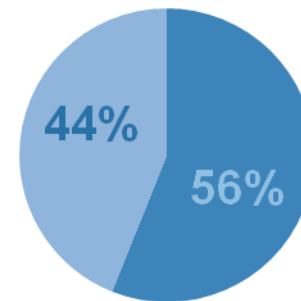
Sector of growth:
VVER-1000, 1200



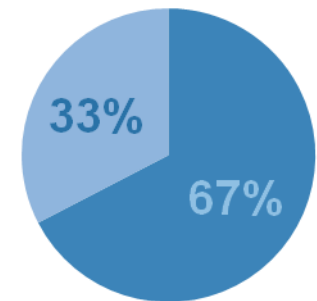
Sector of functioning:
RBMK-1000



Phase-out sector:
VVER-440, AMB,
EGP



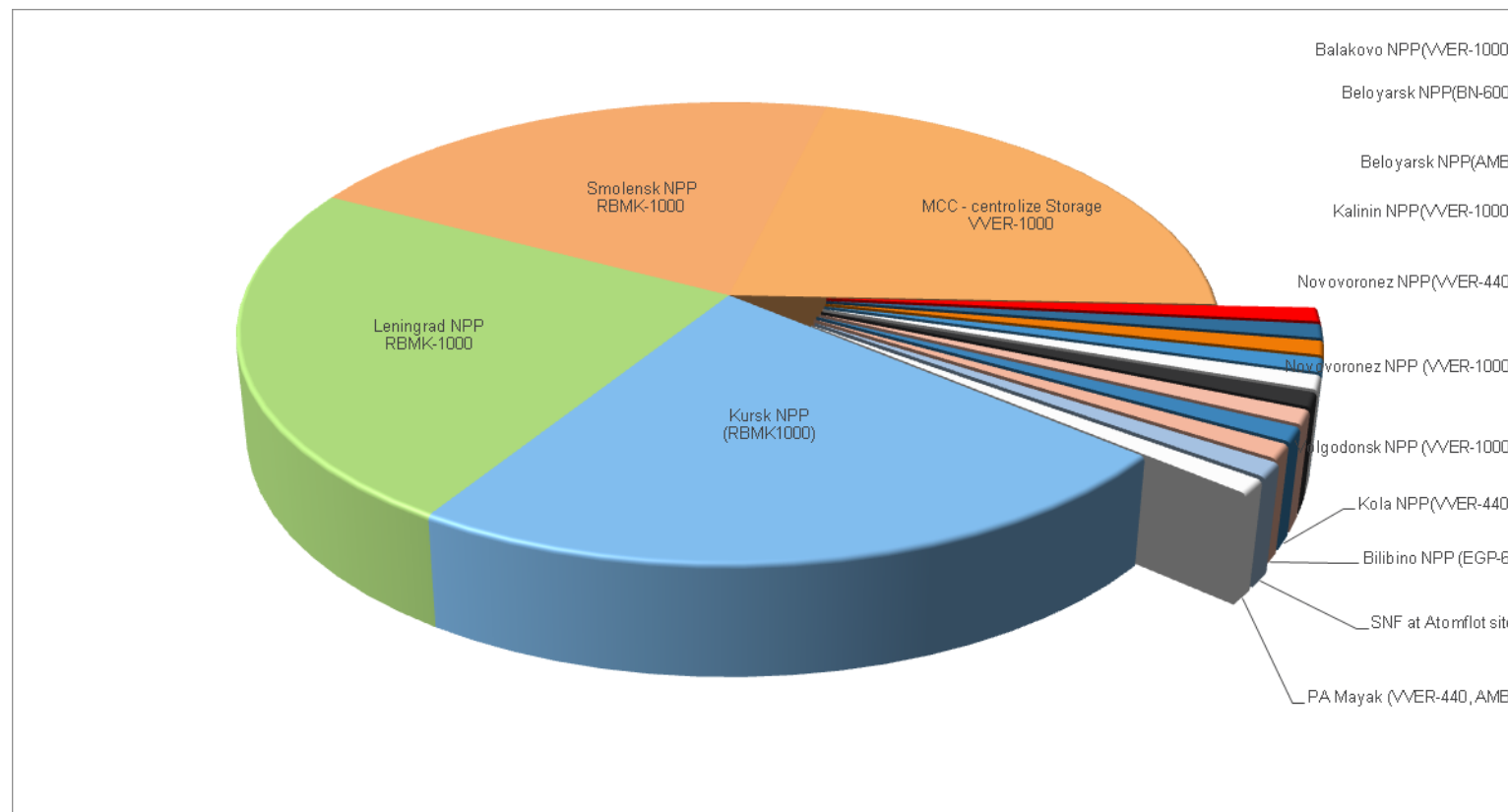
Development
sector:
Fast reactors



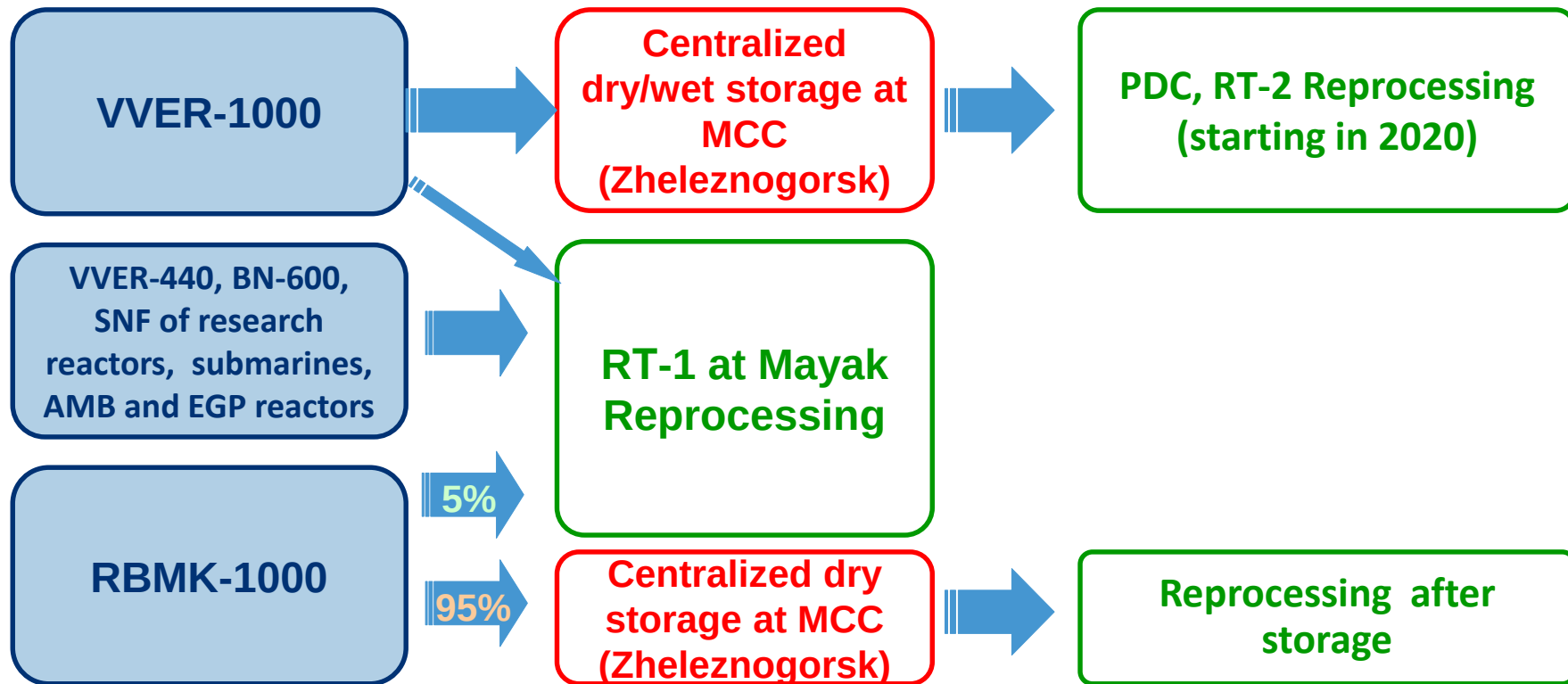
- Accrued operational life
- Residual lifetime

- Fleet of various reactors should be equipped with different technologic facilities of SNF management
- Commissioning of numerous VVER-1000, 1200 NPP units

Accumulation of spent nuclear fuel at Rosatom enterprises' site



Technologic Patterns of UNF Management: Temporal Storage and Reprocessing



Reprocessing is a basic method of UNF management

RT-1 Reprocessing Plant in Ozersk.

The first SNF Reprocessing Facility in Russia



- UNF reprocessing plant in Russia
- Operation since 1977
- Over 5000 ton of SNF reprocessed
- Annual reprocessing of appr. 200 tons of SNF (from VVER-440, BN-600, VVER-1000, damaged spent fuel from RBMKs, research reactors, icebreakers and submarines)
- The list of the reprocessed SNF is diversifying (plans for reprocessing of SNF from AMB, EGP and all the types of research reactors)
- The technology of reprocessing : Purex-process (extraction of regenerated Uranium, Plutonium and Neptunium as the reprocessing products)
- Enhancement of RW management system
- Production of isotopes Cs-137, Am-241, Pu-238, Sr-90

The infrastructure of SNF management at Mining and Chemical Combine at Zheleznogorsk



- Centralized water-cooled (“wet”) SNF storage facility;
- Centralized air-cooled (“dry”) SNF storage facility;
- Pilot Demonstration Center for innovation-based SNF treatment;
- MOX fuel fabrication for fast neutron BN-800 type reactors.

SNF centralized storing complex at MCC”



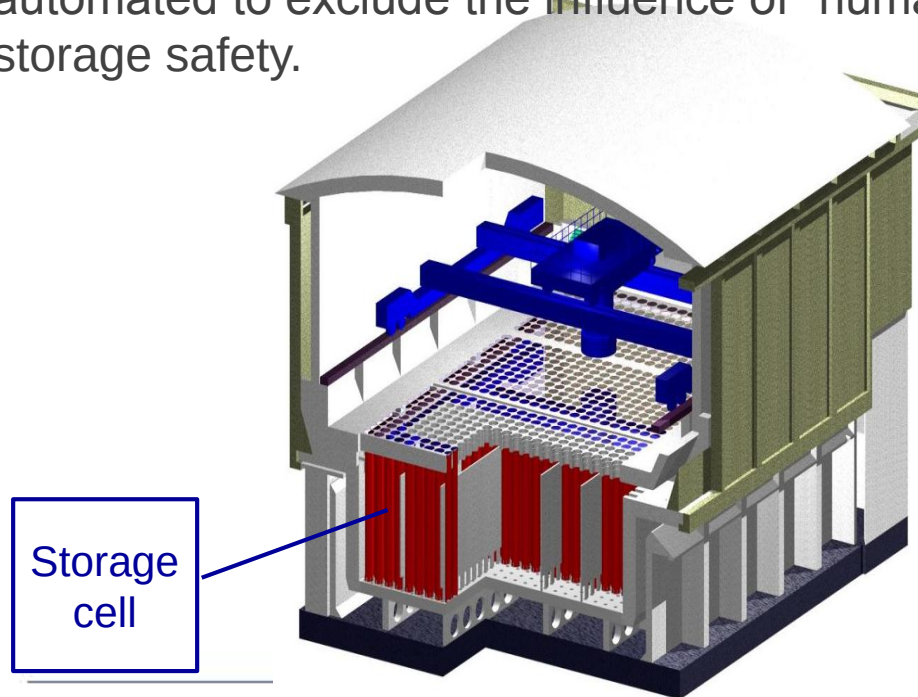
The full-scale storage complex for SNF from RBMK-1000 and VVER-1000 was built in December 2015.

Constructions maintain integrity under earthquake load up to 9.6 points and withstand direct plane crash.

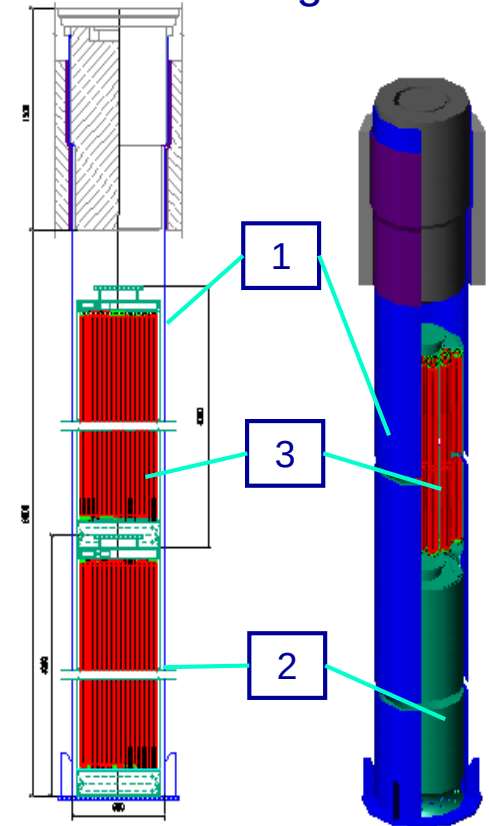
“Dry” centralized storage

The “dry” storing technology is based on the **passive principle of safety protection** in case of a power supply loss all conditions of safe SNF storing will be retained thanks to the **natural air-cooling convection**.

All engineering operations while transferring SNF to the storage as well as the storing process itself are fully automated to exclude the influence of “human factor” on SNF storage safety.

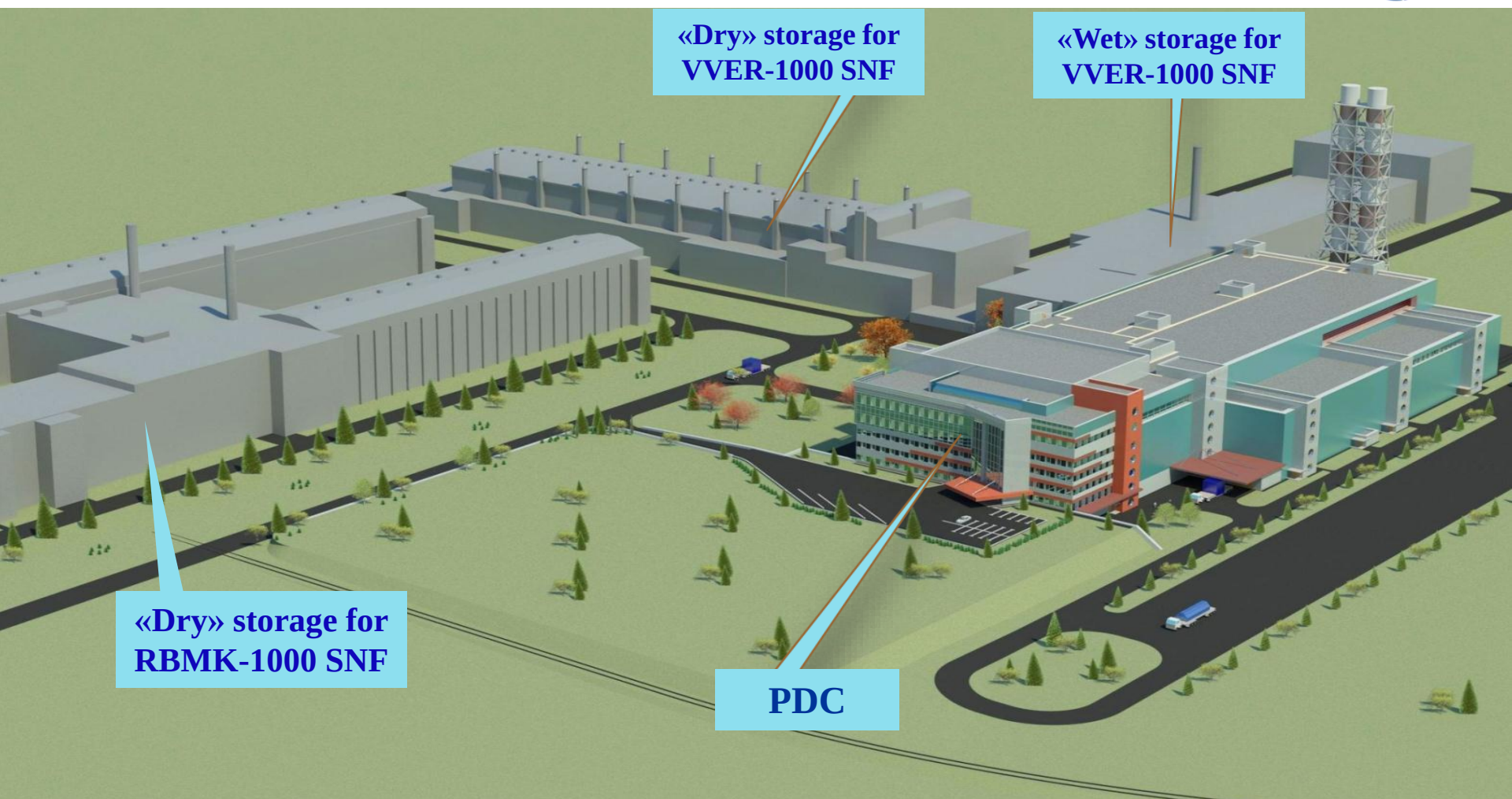


Storage cell



- 1 – storing seat;
- 2 – case with gas ($N_2 + He_2$);
- 3 – fuel element of assembly

PDC in SNF management complex



2015 – Construction of PDC's first start-up complex is finished.

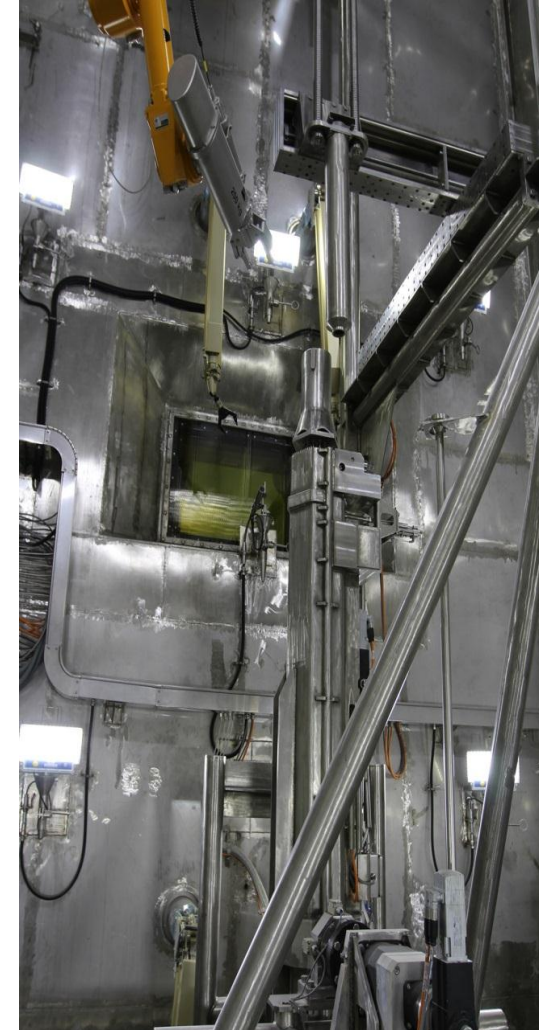
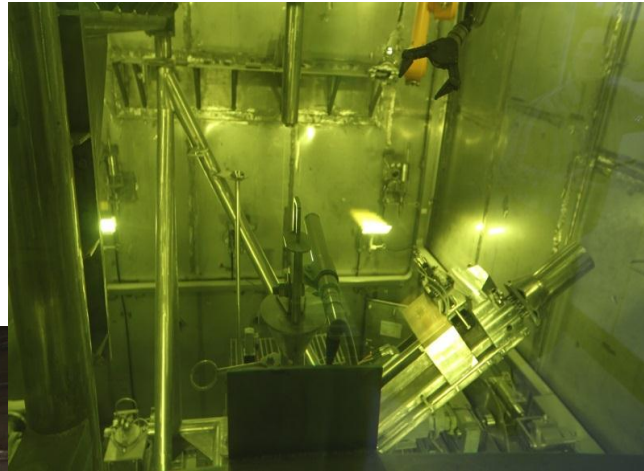
2020 – Full-scale PDC commissioning with capacity of reprocessing 250 tons of SNF annually. The innovative reprocessing plant of the third generation – no RW release.

Initial data to be received for the large-scale commercial plant for SNF reprocessing.

Pilot Demonstration Center for SNF reprocessing

2016 – Start-up facility of research hot cells starts operation.

New treatment technologies of SNF from both thermal and fast neutron energy reactors along with closing the NFC

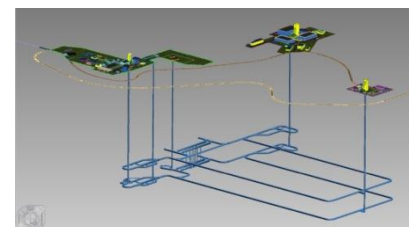


Radioactive waste generation after thermal reactors UNF reprocessing at PDC

Radioactive waste volumes:	Existing technologies	Pilot-demonstration Center Technology
Vitrified HLW m ³ /t SNF	~ 0,6	0,1
Solidified intermediate level waste , m ³ /t SNF	~ 40	3,0
Low level liquid radwaste volume (Controlled release of effluents) , m ³ /t SNF	~ 100	No

By-product management

- Utilization Rep U – fuel fabrication for LWR
- Utilization Pu - fuel fabrication for FR & LWR
- RW – conditioning for storage and disposal



MOX-fuel production to fuel supply fast reactor BN-800

MOX fuel fabrication industrial plant was constructed at MCC in 2014.

For Russia, this is the first step towards commercial involvement of the plutonium potential into the nuclear fuel cycle by closing the nuclear fuel cycle at BN-800 fast neutron reactors

Loading of the full active zone BN-800 by MOX fuel is scheduled for 2019.



System for fuel pellets sintering,
MOX fuel fabrication



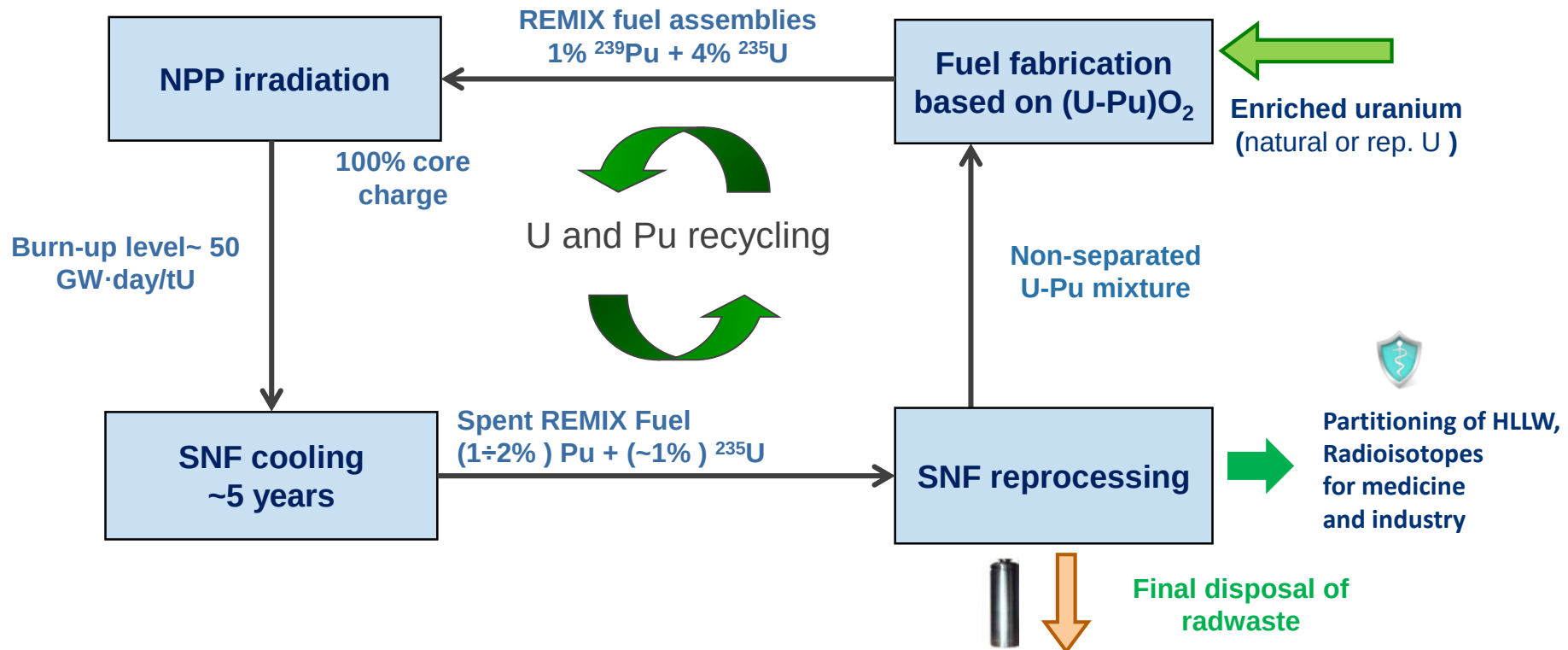
System for assembling fuel rods into
the final fuel assembly structure

REMIX fuel – U& Pu multi - recycling in thermal reactors (VVER-1000)

REMIX fuel is the mixture of U and Pu from LWR SNF reprocessing, with the addition of enriched uranium (natural and rep. U)

2014 – start of the project for 3 experimental Fas REMIX fuel fabrication and irradiation in RR and NPP .

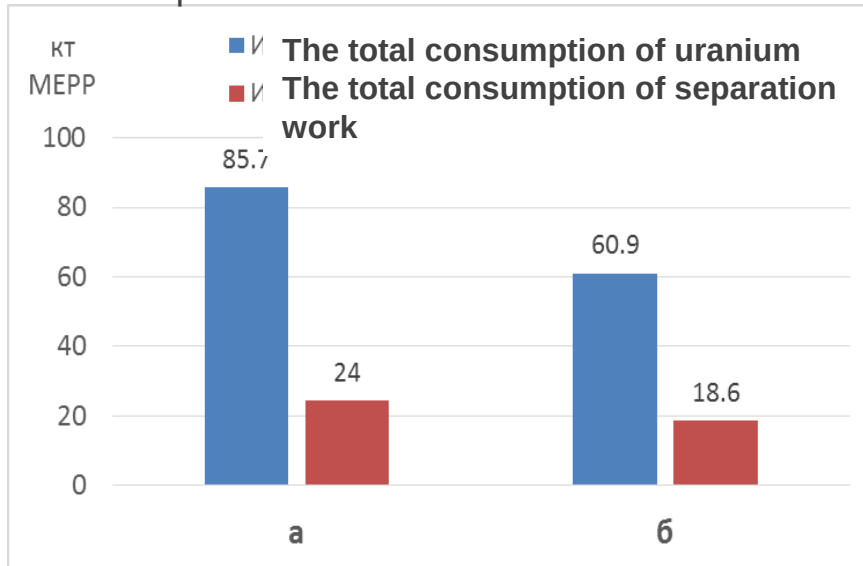
2017 – 2017 – start of the project for REMIX fuel fabrication pilot plant, and safety case for REMIX fuel developing



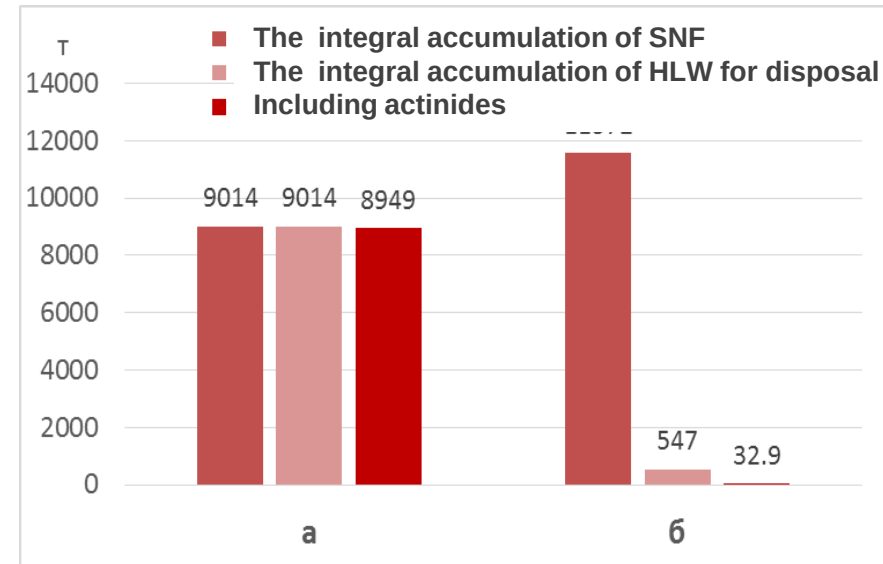
Integral indicators of fuel balance in REMIX- NFC (60 years life cycle)



The total consumption of uranium and separation work



Integral accumulation of SNF / HLW



- a) Open NFC with increased burn up (70 GW/t) UOX-fuel
b) Closed NFC with REMIX fuel (50 GW/t burn up)

Closed NFC with REMIX-fuel: the benefits

Save natural U and separation works (the integral consumption for 60 years is reduced by 25% compared to Open NFC)

All Pu and rep U returns back into the fuel cycle, all spent fuel is recycled (dramatically reduce the total number of stored spent fuel and HLW about 6 times in the end of the life cycle of NPS) ; 5 cycles REMIX fuels completely cover the 60-year term of life of the reactor - the reactor can work "on same" fuel (with feeds by the enriched uranium

The "quality" waste for final disposal (the content of long-lived actinides) are fundamentally improved: in Open NFC in this category all SNF, in REMIX CNFC all the uranium and plutonium from spent fuel back to regenerated.

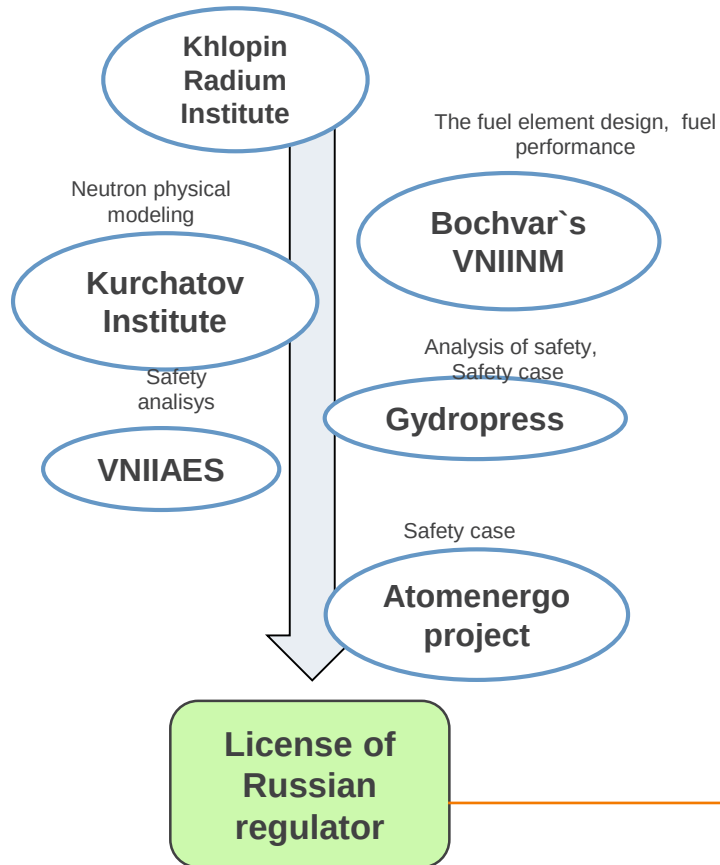
REMIX fuel it is possible to load 100% of an active zone of the VVER reactor;

Don't need considerable expenditure for modernization of the NPP equipment ;

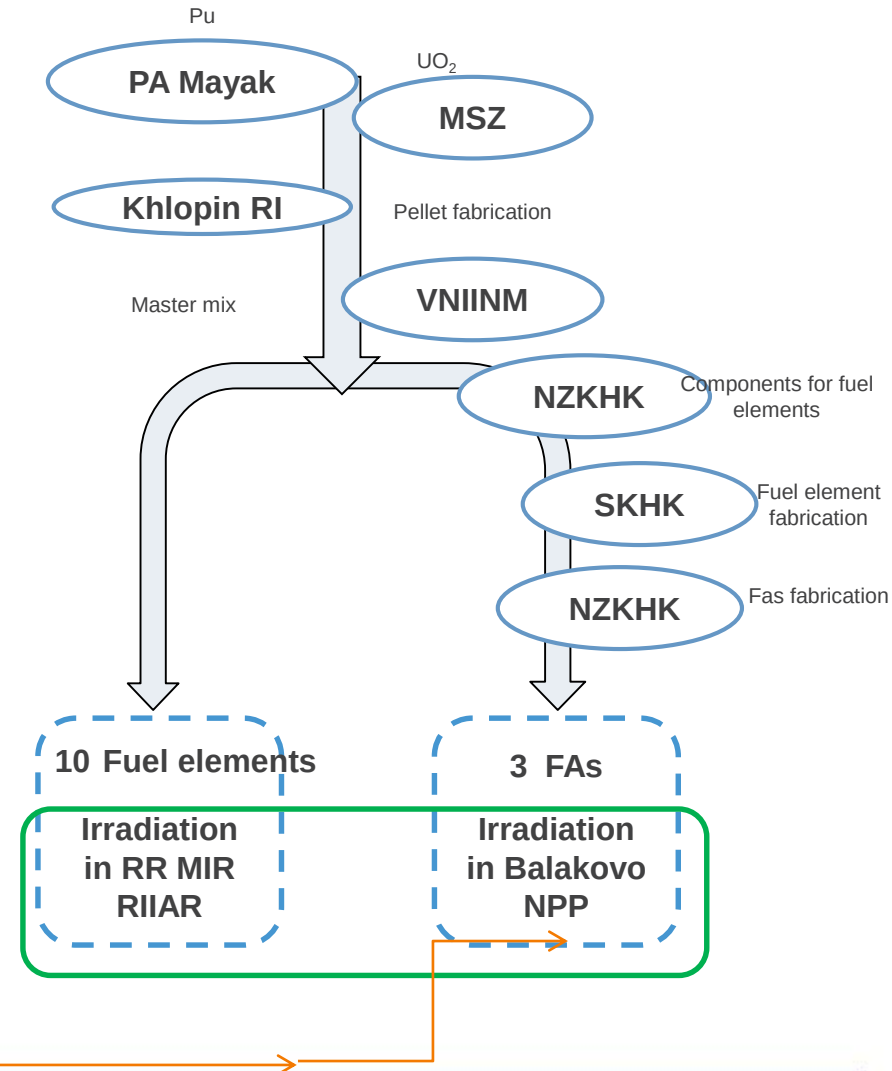
the full guarantee of non-proliferation –no pure plutonium.

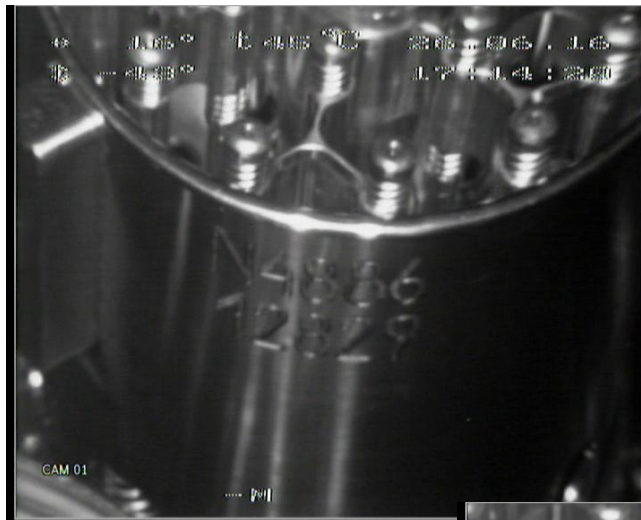
2014 - 2016 – Rosatom`s project activity for 3 experimental Fas REMIX fuel fabrication and irradiation in RR and NPP

Safety justification



Fabrication





Experimental fuel assemblies with fuel rods containing fuel REMIX – installed in the reactor

FAs with REMIX fuel loading in reactor core (Balakovo NPP)



2017 – start of the project for REMIX fuel fabrication pilot plant, and safety case for REMIX fuel developing



ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ
«РОСАТОМ»
(Госкорпорация «Росатом»)

РАСПОРЯЖЕНИЕ

18 июля 2017

Москва

№ 1-1/542-Р

О программе «Реферирование РЕМИКС-топлива для организации его продвижения на зарубежные рынки» и формировании управляющего совета по реализации программы

В настоящее время в рамках стратегического междивизионального инвестиционного проекта «Расчетно-экспериментальное обоснование РЕМИКС-топлива», реализуемого в соответствии приказом Госкорпорации «Росатом» от 14.11.2014 № 1/1098-п, на Балаковской АЭС и в АО «ГНЦ НИИАР» продолжаются работы по реакторным испытаниям экспериментальных ТВС и ТВЭЛ, содержащих РЕМИКС-топливо.

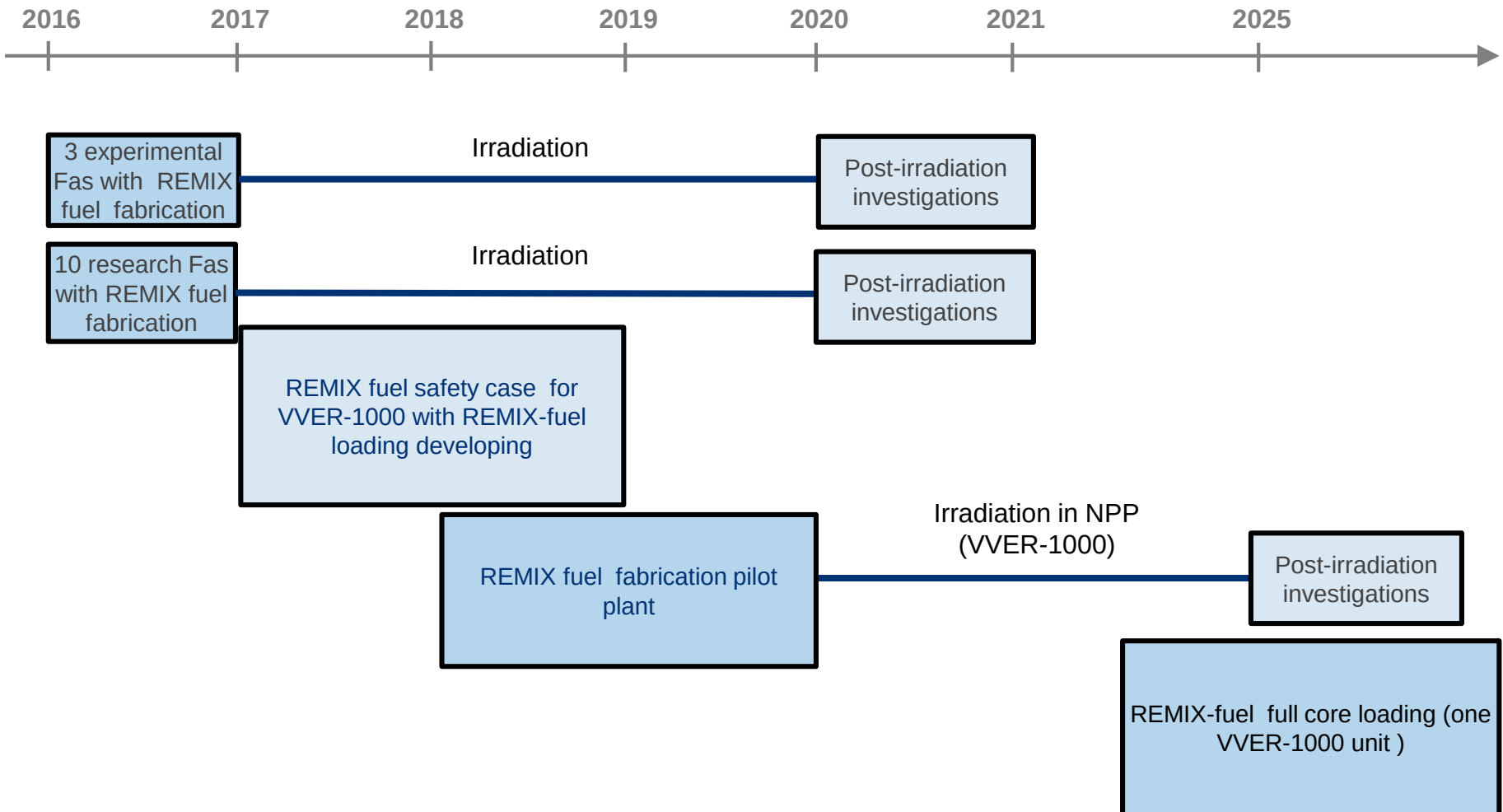
С целью дальнейшего реферирования процессов фабрикации и использования РЕМИКС-топлива для организации продвижения его на зарубежные рынки

ПРИКАЗЫВАЮ:

1. Создать программу «Реферирование РЕМИКС-топлива для организации его продвижения на зарубежные рынки» (далее – Программа).
2. Установить, что в состав Программы входят три проекта:
 - 2.1. Проект «Расчетно-экспериментальное обоснование РЕМИКС-топлива».
 - 2.2. Проект «Обоснование безопасности опытно-промышленной эксплуатации РУ типа ВВЭР-1000 с ТВС-2М с РЕМИКС-топливом, включая транспортно-логистическую схему обращения с РЕМИКС-топливом на АЭС» (далее – проект «Обоснование безопасности РЕМИКС»).
 - 2.3. Проект «Создание технологии и обоснование опытно-промышленного производства РЕМИКС-топлива» (далее – проект «Фабрикация РЕМИКС»).
3. Определить оператором Программы Госкорпорацию «Росатом».
4. Назначить:
первого заместителя генерального директора – директора Блока по развитию и международному бизнесу Комарова К.Б. заказчиком Программы;
директора по государственной политике в области РАО, ОЯТ и ВЭ ЯРОО Крюкова О.В. руководителем Программы;
5. Сформировать управляющий совет Программы в соответствии с приложением к настоящему распоряжению.

The start of the project
for REMIX fuel
fabrication pilot plant,
and REMIX fuel safety
case developing
is approved by the
decision of Rosatom
in July, 2017

The stages of the project for REMIX fuel fabrication pilot plant, and REMIX fuel safety case developing



Site for REMIX fuel fabrication pilot plant - MCC

- The creation of the integrated complex for SNF management (including storage, reprocessing, MOX-fuel fabrication) is under finishing.
- Sitting REMIX fuel fabrication pilot plant at MCC will allow to significantly reduce the investment and logistic expenses
- Existence of the natural containment.
- The cost of reprocessing and recycling at the integrated plant is significantly less (520-710\$/kg for reprocessing and a fabrication uranium - plutonium fuel) than for separate activities (1000\$/kg for reprocessing and 1500\$/kg for a fabrication uranium - plutonium fuel)(IAEA estimates)

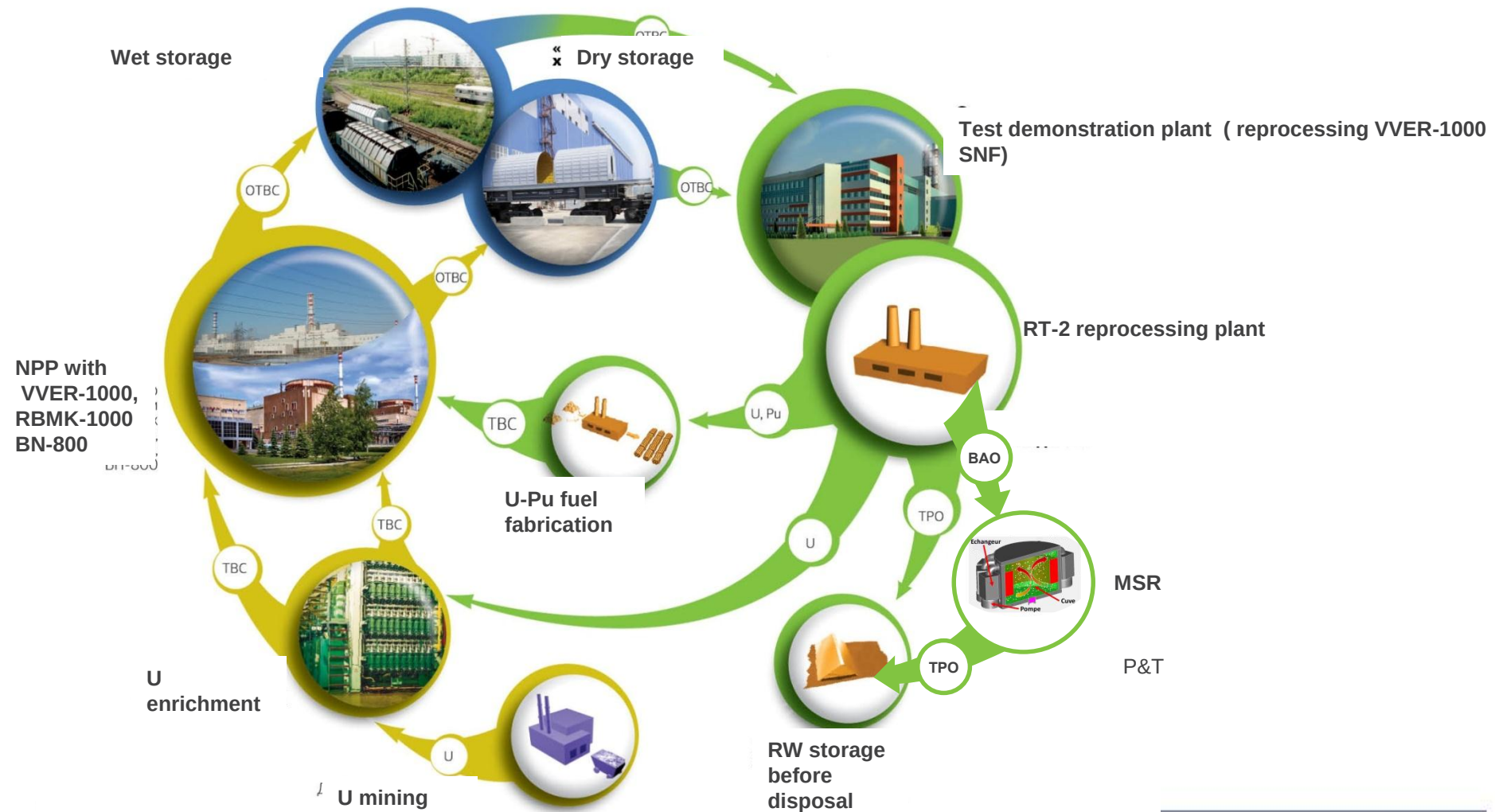
Table 2. Comparison of Unit Costs for Various Treatment Options (from literature sources)

Cost Component	Units	OECD/ NEA (1994)	OECD/ NEA* (2002)	DOE GEN- IV** (2002)	MIT (2003)	Bunn (2003)	BCG (2006)	MARKET 2006 end (Ux)
Natural Uranium	\$/kgU	40-50-90	20-80	20-30-80	30	40	80	190
Conversion	\$/kgU	6-8-11	3-8	3-5-8	8	4-6-8	12	14
Enrichment	\$/kgSWU	80-110-130	80-120	50-80-120	100	50-100-150	110	135
UOX Fabrication	\$/kgU	200-275-350	200-300	200-250-300	275	150-250-350	200	-
SF storage		60-230-290	100-300	210-410-640	400		920(1) 500(2)	-
SF disposal	\$/kgHM	200-840-960	300-600				Disposal included	-
UOX Reprocessing	\$/kgHM	540-720-720	500-900	500-800-1,100	1,000	1,000	110(1) 520(2)	-
HLW storage/disposal	\$/kgHM	90-150-190	80-200	80-200-310	300	0-150-300 less than SF	RepU+ MOX fab & credit recycled fuel included	-
MOX fabrication	\$/kgHM	825-1,100-1,375	1,000-1,500	600-1,100-1,750	1,500	700-1,500-2,300		-

(1) in undiscounted costs per KgHM in used fuel

(2) in discounted costs per KgHM in used fuel

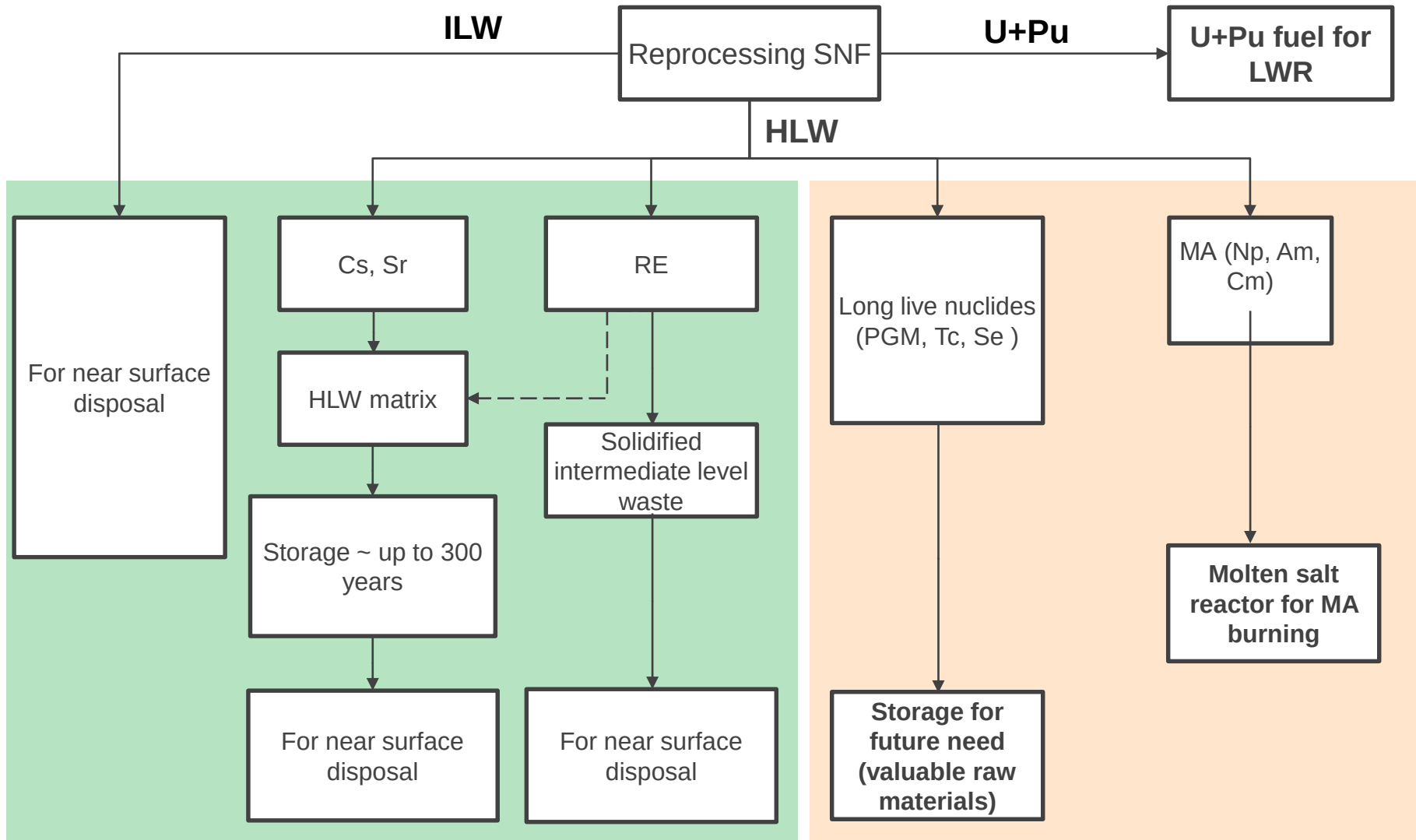
The concept for SNF management integrated plant



HLLW partitioning – no need of the geological disposal site for the new comer country customer



POCATOM



RW for returning to the customer

It is used NFC in Russia

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