ROSATOM

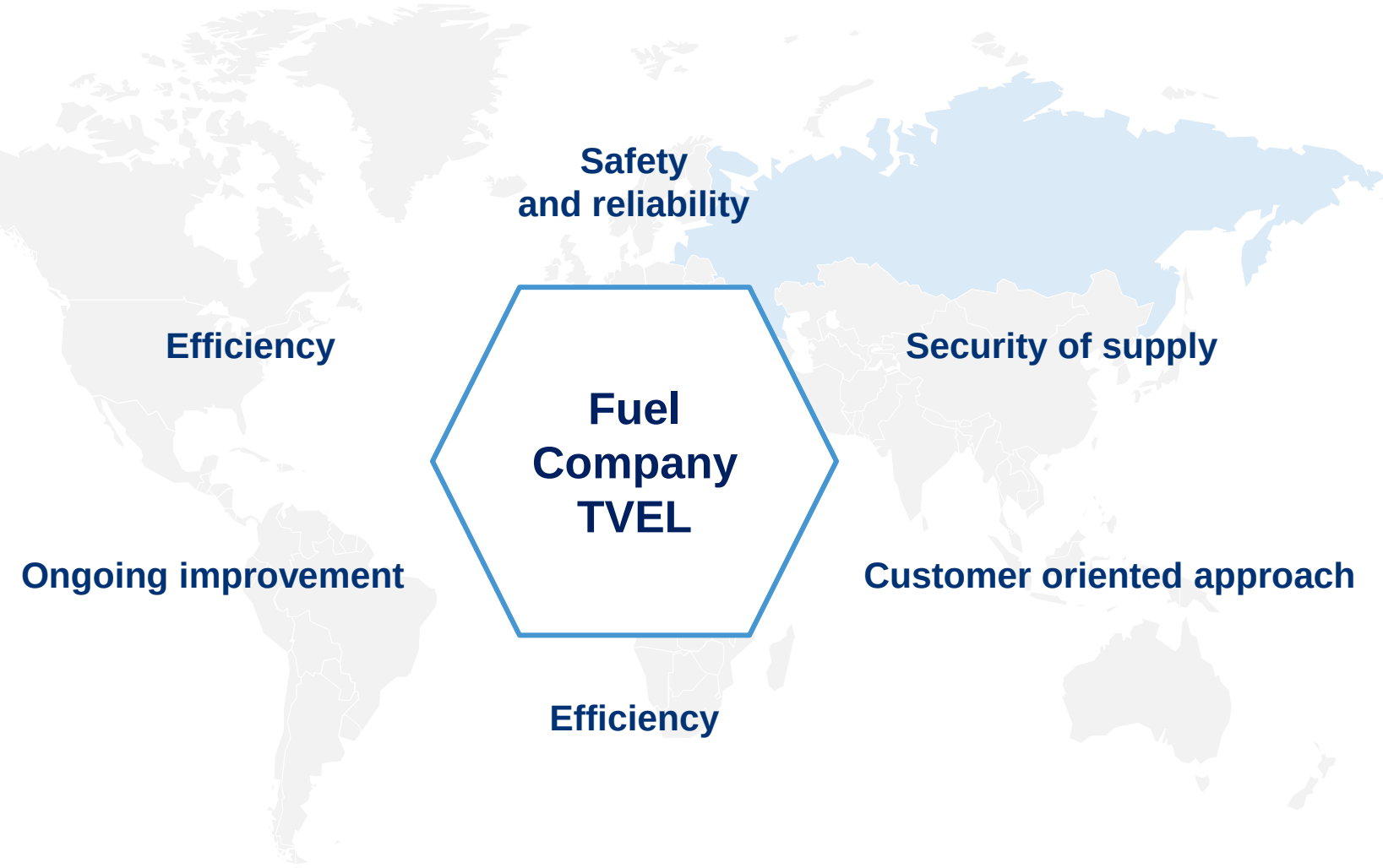
STATE ATOMIC ENERGY CORPORATION ROSATOM

Fuel Company TVEL – reliable supplier of nuclear fuel

November, 19
2014

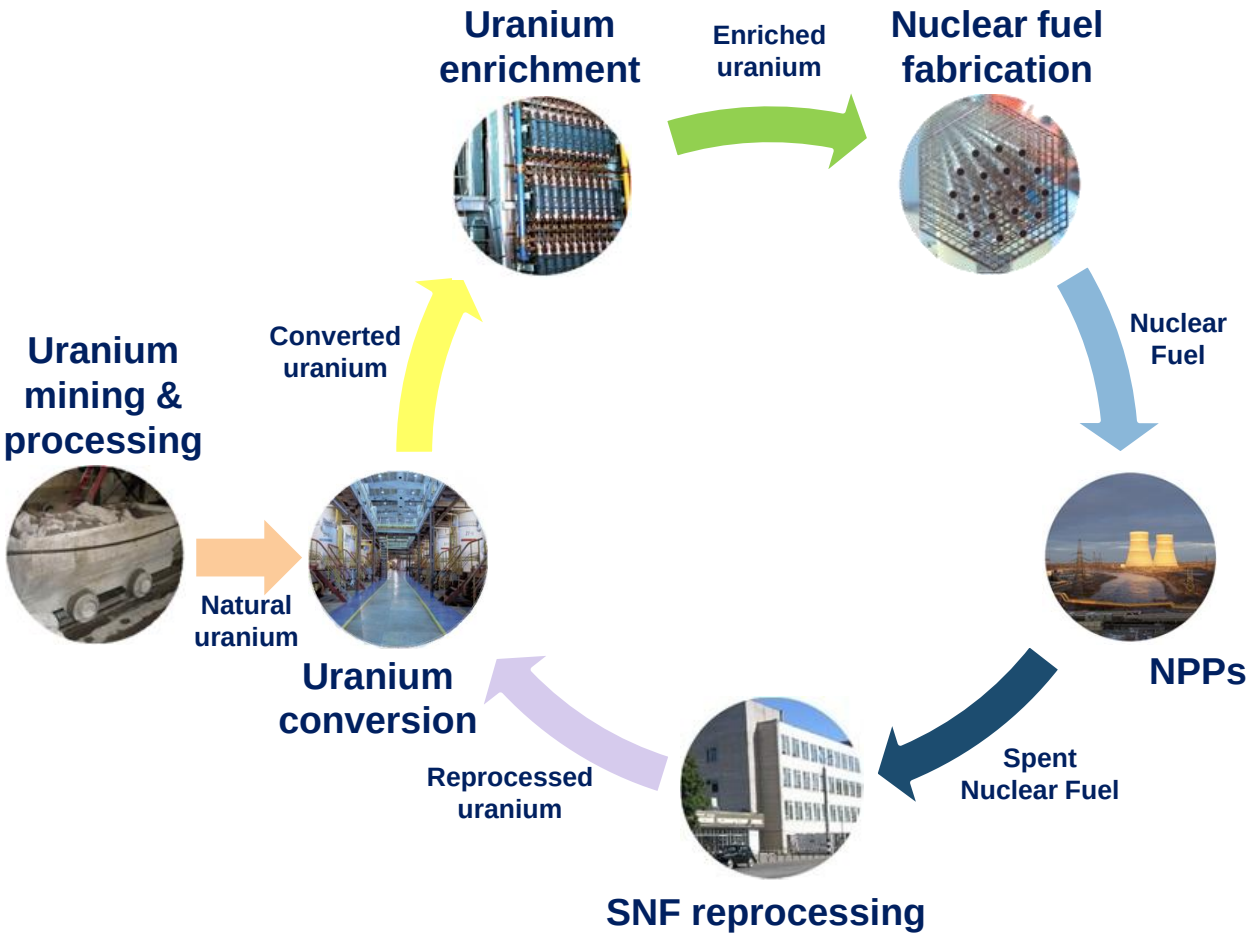
Fuel Company TVEL – decades of security of supply

Values of Fuel Company TVEL



Rosatom Nuclear Fuel Cycle

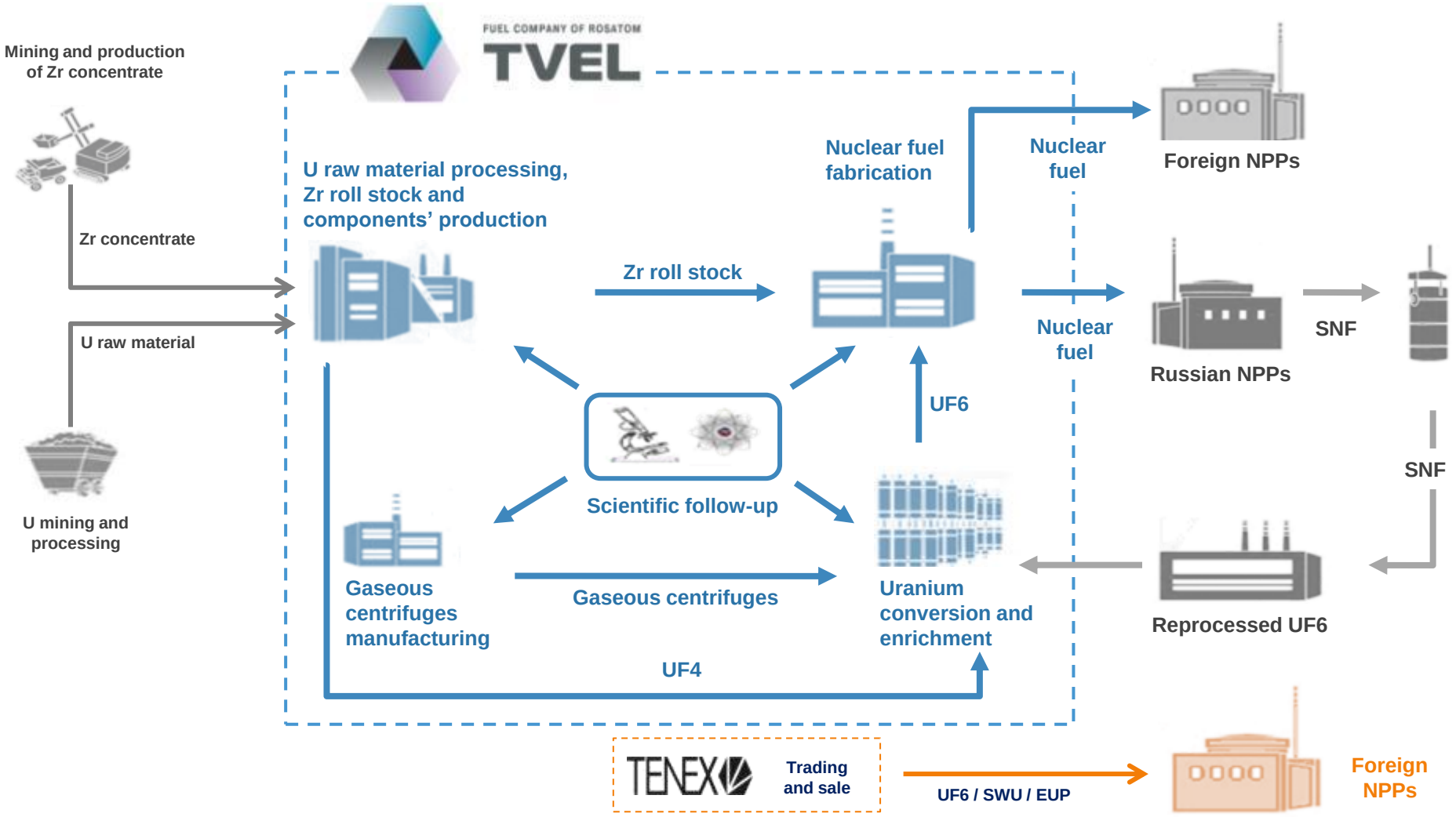
Rosatom has unique competences and integrated assets within all front and back end of Nuclear Fuel Cycle…



…being the leader on the world Nuclear Fuel Cycle market

- #2 globally in natural uranium deposits
- 8 200 t. uranium produced in 2013
- #1 in globally in uranium enrichment production base
- 45% of the world uranium enrichment services market
- 17% of the world nuclear fuel market
- Supply for 77 power reactors in 15 countries all over the world

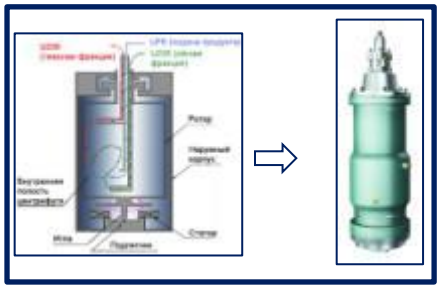
TVEL in Russian Nuclear Fuel Cycle



TVEL: Products and Services

(1) Conversion services of of U3O8 into UF6

(2) Enrichment of U raw material for NPPs



Design and production of gaseous centrifuges, as well as auxiliary equipment for U isotopes separation

Gaseous centrifuges

U raw material: SC Rosatom

Uranium

Uranium conversion and enrichment

Nuclear Fuel

R&D

(1) Development of FAs designs

(2) Fabrication of nuclear fuel components

(3) FA fabrication for various reactors

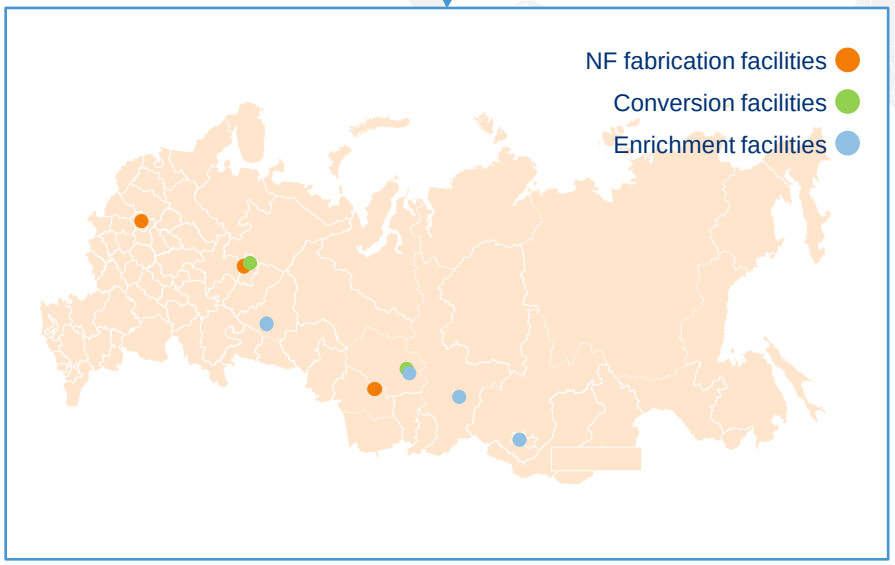
Various supply terms

- ✓ FAs are allowed for transportation only if the approval certificate confirming the compliance of the Transport Package (PCS) design with the **requirements of IAEA** «Safety Regulations for Radioactive Material Transportation» TS-R-1 is available;
- ✓ FA capacity – 2 pcs;
- ✓ Service life – 20 years
- ✓ TVEL's fuel casks are **transportable by any type of vehicle**;
- ✓ TVEL's fuel casks are the only type of cask which **passes full-scale test** (incl. acceleration up to 90 m/c);
- ✓ TVEL's fuel casks are equipped with shock sensors (supply terms control).

Fuel Company TVEL on the global NF market. International cooperation.

Fuel Company TVEL today: nuclear fuel for NPPs in 15 countries

(1) NF for NPPs of Russian design – our traditional market
(2) NF from RepU for European reactors in cooperation with AREVA
(3) NF for PWR – Russian design TVS-K



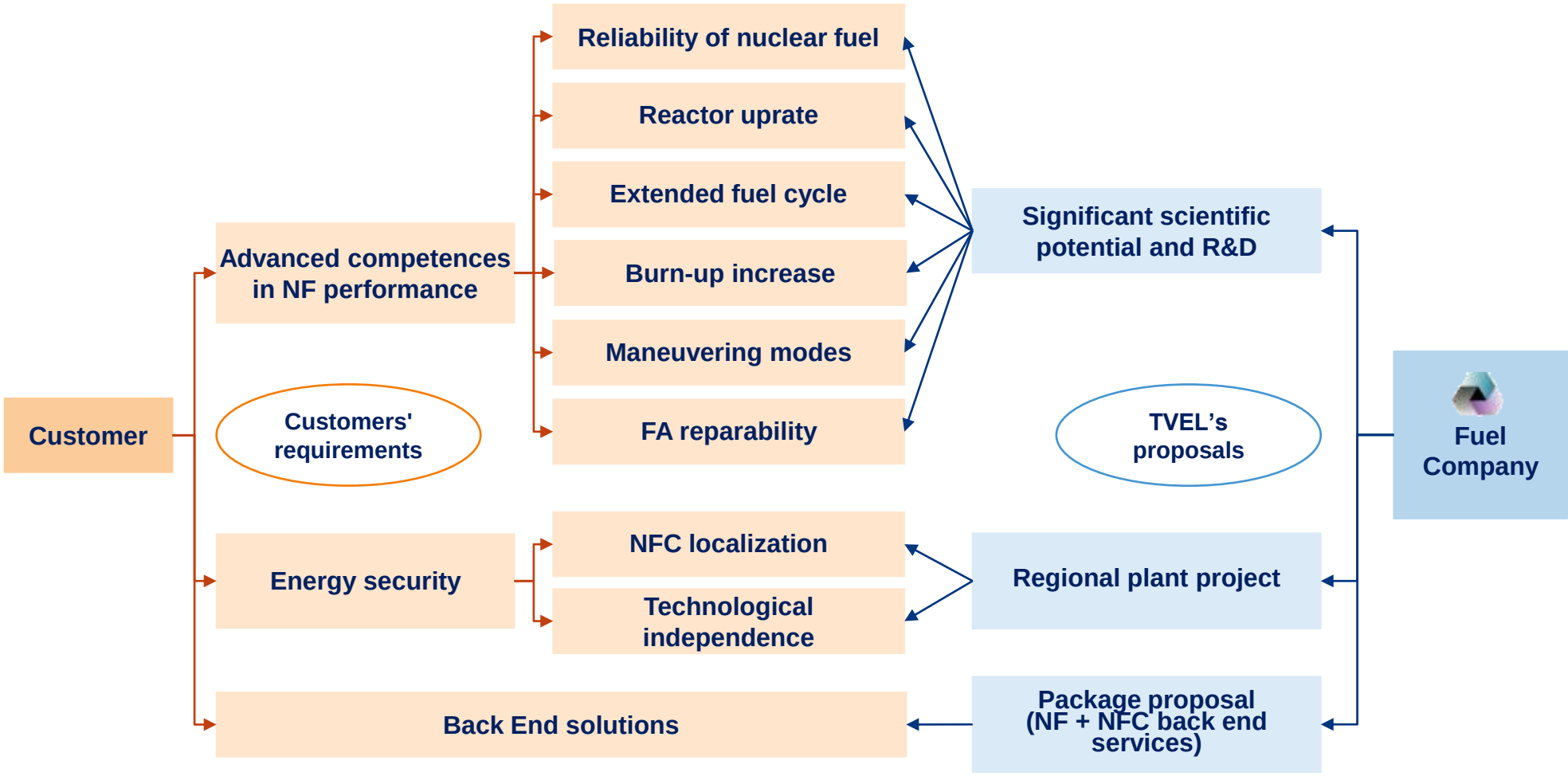
Countries using TVEL's NF, including fuel for NPPs of Russian design, fuel produced in cooperation with AREVA and TVS-K

Located in different parts of the country **facilities of front end of NFC** – conversion, enrichment and fuel fabrication – allow **cooperation on wide range of issues in different formats**

New opportunities for our customers

yesterday	today	tomorrow
		Set of NFC services: Front End + Back End
		+
	Localization of fabrication facilities	Localization of fabrication facilities
	+	+
Ongoing improvement of nuclear fuel performance	Ongoing improvement of nuclear fuel performance	Ongoing improvement of nuclear fuel performance

Customer oriented approach



Fuel Company TVEL together with its customers works on increase of economic efficiency of the nuclear energy

Common procurement policies in NFC.

TVEL's proposal for key issue of nuclear program – fuel supply

Most common procurement policies in NFC

1 Bundled services procurement

Utility buys U, conversion, enrichment and fabrication services **from the one supplier**

- ✚ All the risks of disruptions are on the supplier
- ✚ Savings on procurement stuff and logistic expenses
- ✚ The most comfortable “one window approach”
- ▬ Discourage of competition (?)

The most comfortable option to start

2 Competitive procurement

Utility buys U, conversion, enrichment and fabrication services **from different suppliers**

- ✚ Security of supply via sources’ diversification
- ✚ Opportunity to get the best contract terms & conditions
- ▬ Complexity (need for relevant competences)
- ▬ Time intensive
- ▬ Risks of disruptions are on the Utility

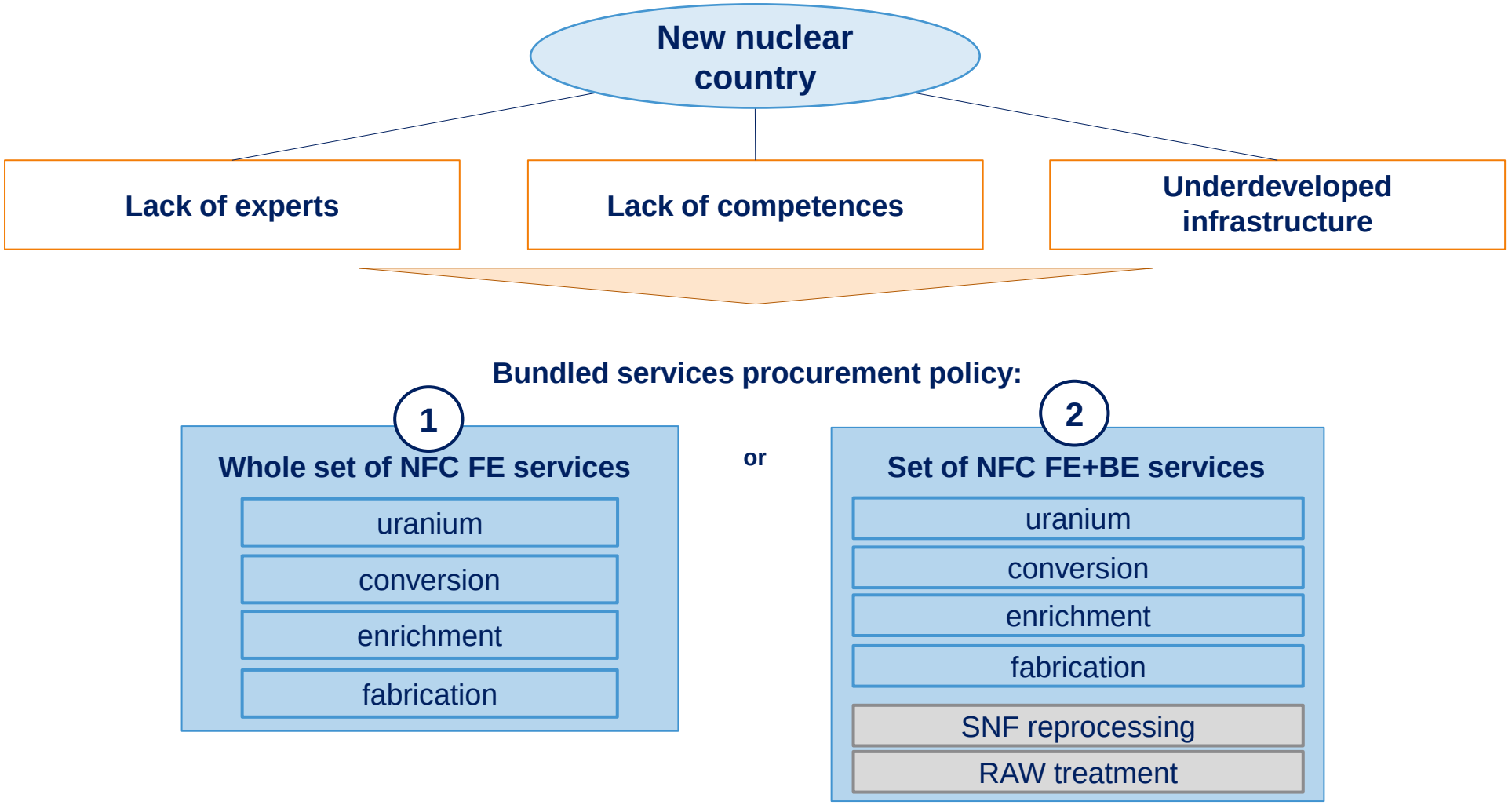
3 Production (Localization)

Utility has **assets** in U mining or other stages of NFC

- ✚ Security of supply (via direct control)
- ✚ Business expansion opportunities (export)
- ✚ Competences’ diversification
- ▬ Complexity
- ▬ Capital consuming
- ▬ ROI is under question
- ▬ Time intensive

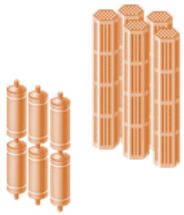
Possible evolution of procurement policies in emerging countries

Challenges in the field of Nuclear Fuel Cycle for new nuclear countries



Rosatom Integrated NFC Solutions

Usual NFC supply approach



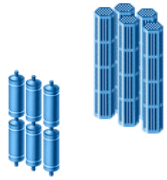
Nuclear Fuel

NPP

Issues for the Customer

- Wet short-time SNF storage or dry long-time one?
- Reprocessing or final disposal?
- How and where to pack RW?
- How to ship the SNF?
- What should be the mode of decommissioning?
- What to do with reprocessed U and Pu?

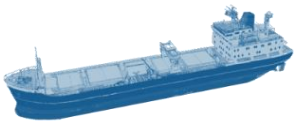
Rosatom Integrated NFC proposal



Nuclear Fuel

NPP

Interim Storage



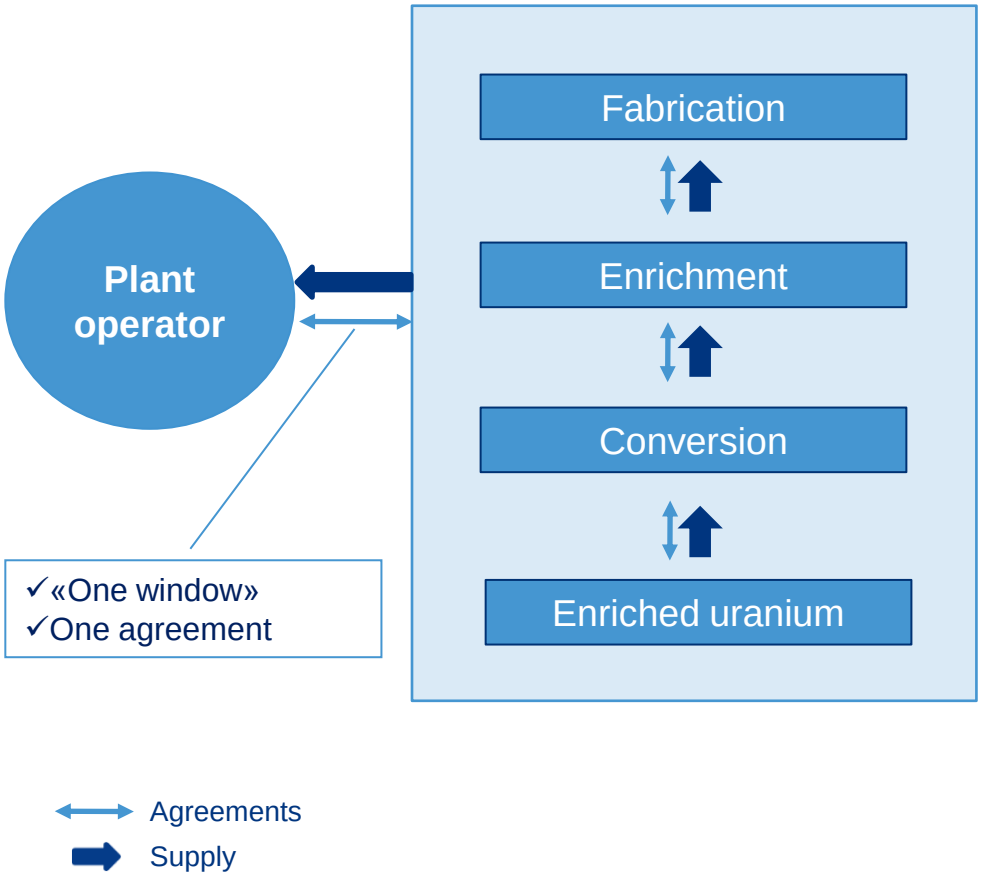
Shipment

Regenerated Materials

Reprocessing in Russia

1. Set of NF Front End services. Advantages

NF package supply

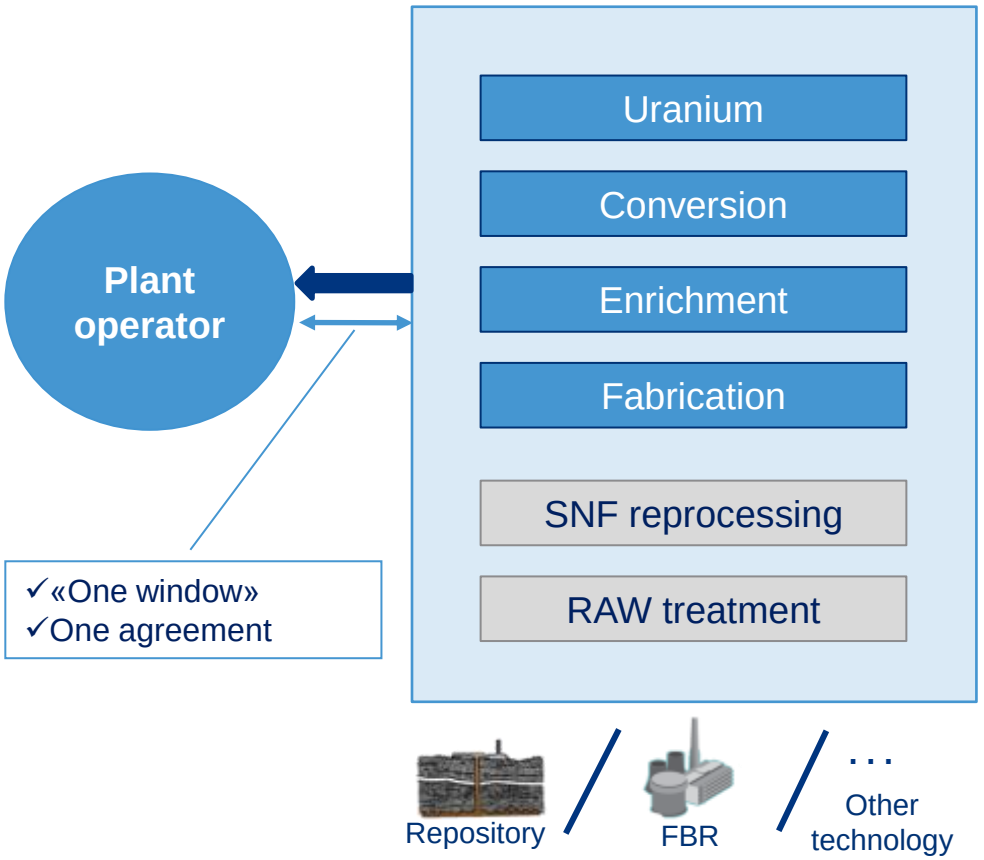


Package supply advantages

- ✓ No risk for operator in finding and purchasing products and services of NFC FE as well as in logistics
- ✓ Plant operator does not bear the expenses incidental to separate contraction
- ✓ Best possible price offer for all range of NF front end services
- ✓ The ability to optimize costs of the logistics (all partitions within the same country)

2. Set of NF Front End + Back End services. Advantages

Set of NFC services



Set of NFC services' advantages

✓ **Non-proliferation**

Non-proliferation of Nuclear Dual-Use Technology and Materials

✓ **Safety**

Extensive expertise in SNF/Radwaste management

✓ **Ecology**

Efficient use of natural resources

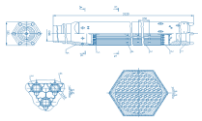
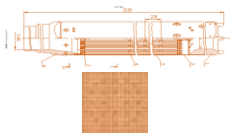
Reduction of radwastes volume and number of hazardous objects

✓ **Economy**

No requirement of FC Back End establishment

TVEL's competences in nuclear fuel fabrication

Competences in Nuclear Fuel Design & Fabrication

	Design	Zr-parts	Powder	Pellets	FA
VVER					
BN					
PWR	 *	 *	 * and **	 * and **	 * and **
BWR			 **	 **	 **
PHWR					

* TVS-K Project

** In cooperation with AREVA

Assembly design and properties. Design evolution

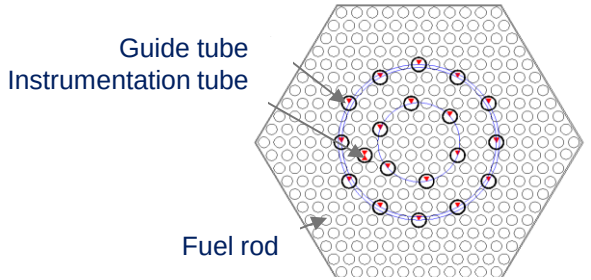
VVER fuel

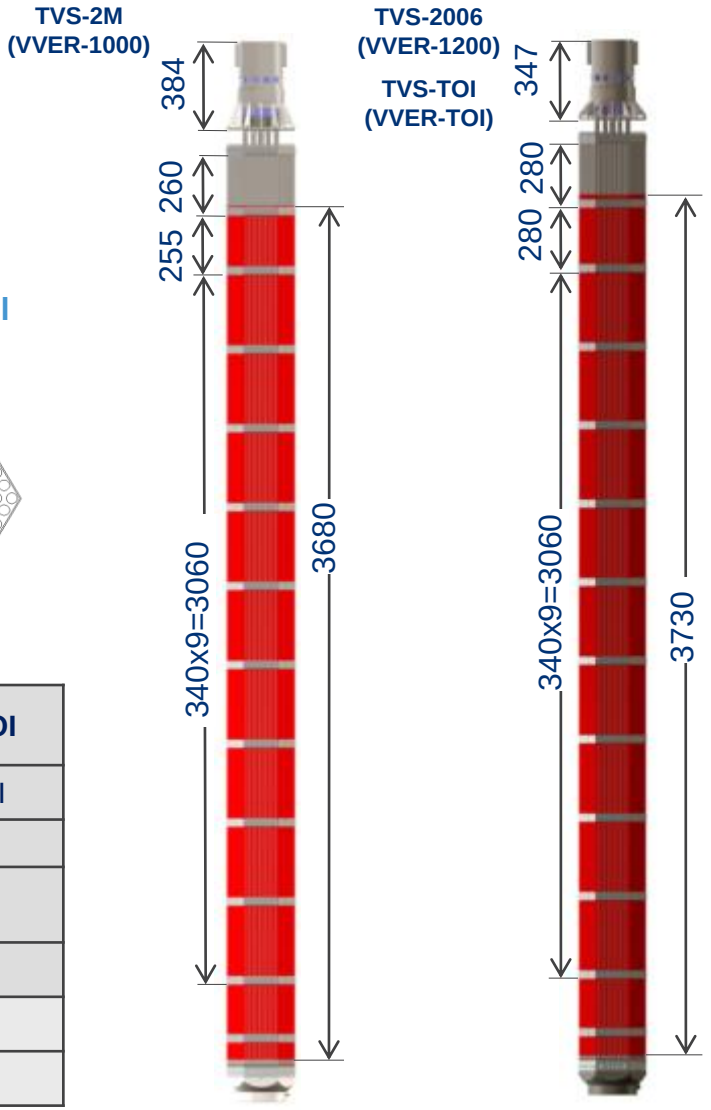
- ✓ Resistance to shape deformation
- ✓ Ability of being disassembled
- ✓ Uranium content
- ✓ Small vulnerability at fuel handling
- ✓ Processability
- ✓ Optimized pitch – 340 mm.

TVS-2006

- ✓ Independent choice of coordinates for ICIS of RCCA position in the cell
- ✓ Bundle asymmetry. Area of increased heat rate

Location of instrumental channel



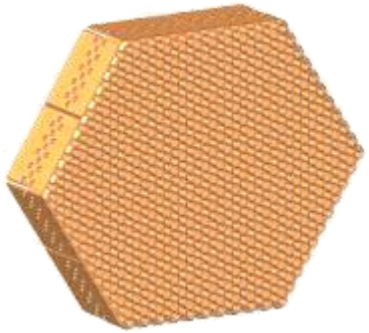


	VVER-1000	VVER-1200	VVER-TOI
FA type	TVS-2M	TVS-2006	TVS-TOI
Mass of fuel in FA, kg	527	534	536
Quantity of guide and instrumentation tubes, pcs.	18+1		18
Quantity of fuel rods in FA, pcs.	312		313
Fuel column height, mm	3680	3730	
Pellet dimensions, Dout / Dc.h	7,6x1,2	7,6x1,2	

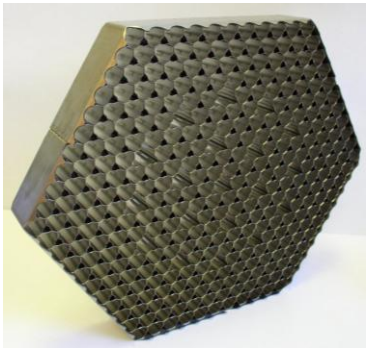
Assembly design and properties. Component standardization

VVER fuel

Lower support shell



Spacer grid



FA top nozzle and collet assembled

Welded skeleton

Ongoing fuel R&D

VVER fuel

Key point – Provide the customer with fuel that ensures:

- **Reliable and safe operation**
- **Economic efficiency in different fuel cycles**
- **Competitiveness**

Improvement directions

- **Reactor uprate**
- **Fuel cycle length extension**
- **FA reparability**
- **Maneuverable reactor operation**

Tasks

1. Design and development of FA that meets the reliability, safety and economic efficiency requirements
2. Development of new and improvement of current fuel compositions and construction materials
3. Improvement of fuel, cladding and FA production technologies
4. Minimizing conservatism of the core analysis, development of computer codes and techniques

VVER nuclear fuel design. Development trends

VVER fuel

FA basic design (2006)	FA design development (TOI)	Increase of enrichment up to more than 5%
Tp= 3200 MWt **Campaign 300 - 540 eff. days** **Enrichment up to 4.95%** **Pellet 7.6/1.2 mm,** **Core height 3730 mm** **UO_2 mass 534 kg** **Burnup 64 MWt days/kg U** **Daily maneuvering** **100-75-100 % N**	Tp= 3300 MWt Enrichment up to 4.95% Pellet 7.8/0мм Core height 3730 мм **UO_2 mass 580 kg** **Heat exchange intensifiers** **Daily maneuvering** **100-50-100 % N** **FA design correction – 2015**	Enrichment up to 7% UEr fuel Zr alloys E110M, E635M & E125 **Substantiation and development of FA design - 2018** **2- year cycle** **(Campaign 680 eff. days)** **Number of feed FA 20% less** **Average burn up rise** **20-25 %** **Lower fuel component 6 - 9 %**

Improvement of calculation codes:

- ✓ Development of codes linked with thermal hydraulic and neutron and physical core calculations;
- ✓ DNB calculation methodology improvement per local parameters;
- ✓ “Best assessment” methodologies and codes application;
- ✓ Using of statistical methods during calculation of DNBR.

Ongoing improvement of reliability and economic efficiency of nuclear fuel

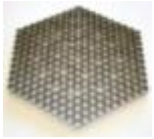
VVER fuel

Safety and reliability of NF operation

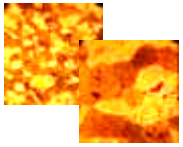
Improvement of FA resistance to distortion: Implementation of FA with robust skeleton

Improvement of protection from foreign materials in the coolant: Implementation of debris filters (DF)

Improvement of resistance to vibration loads: Implementation of antivibration grids (AVG)



Improvement of thermal-hydraulic performance: Implementation of intermediate flow mixers (IFM)



Improvement of PCI behavior, decrease in fission gas release: Increased fuel grain size

Improvement of resistance to corrosion and radiation: Application of new constructional materials

Economic efficiency of NF

Increase in fuel burnup

Elongation of fuel in-core life-time

Creating conditions for units thermal power uprate

Justification of nuclear fuel operation in load-follow modes

Zero Failure Program

VVER fuel

Achievement of “zero failure” condition for nuclear fuel and operation of “clean” cores

Development and implementation of scientific and technological event plan, targeted at detection and elimination of VVER-1000 fuel failure causes

Reducing staff exposure, improvement of environment, reducing fresh fuel costs and spent fuel management costs for NPP, reducing of outage duration

NF Development	NF Fabrication	NF Operation
1. Personnel qualification 2. Well-founded solutions 3. Protection from aggressive operating factors (debris, vibration, etc)	1. Personnel qualification 2. Hardware quality 3. Manufacturing culture 4. Product quality control	1. Personnel qualification 2. Operation mode compliance 3. Assurance of absence of foreign objects in the reactor core 4. Compliance with fuel reload and transportation requirements 5. Compliance with water chemistry requirements

Zero Failure

Development of nuclear fuel fabrication technology (1)

VVER fuel

Section of uranium dioxide powder production by dry conversion technology

Pellets production line

Stacker of pressed pellets in trough for sintering

Equipment for optical inspection of pellets appearance

Fuel pellets on pallets

Development of nuclear fuel fabrication technology (2)

POCATOM

VVER fuel

Fuel rod fabrication line

Robotized complex for assembly and welding of FA skeletons

Optical bench for FA geometry inspection

Automated bench for fuel bundle assembly

Robotized complex for spot welding of spacer grids

TVS-K – Russian Fuel for PWR Reactors

PWR fuel

Fuel Company “TVEL” developed its own independent design of nuclear fuel for PWR reactors – **TVS-K**,
which was designed with due regard to
both development of fuel assemblies for VVER reactors experience
and best international practices.

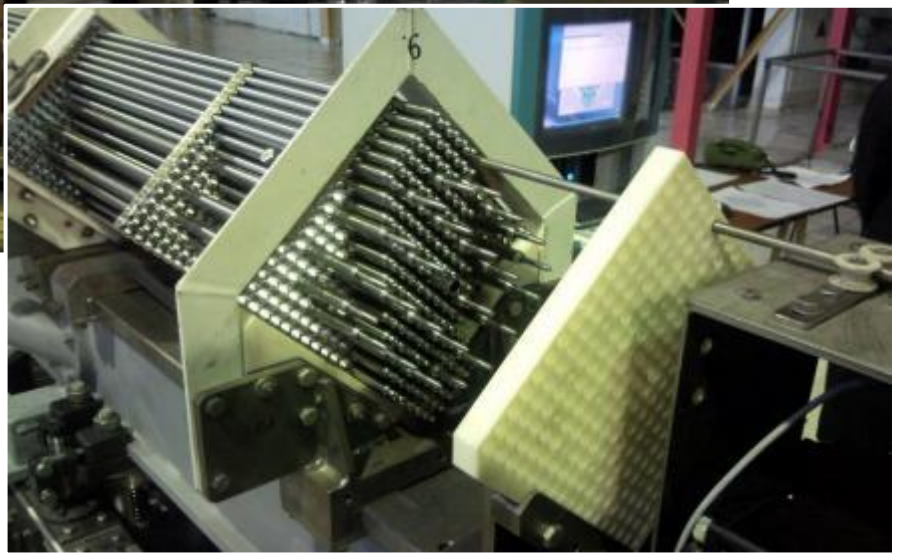
	Characteristic	Value
1	Quantity of fuel rods (U-Gd fuel rods)/GT+IT	264/24+1
2	FA length, mm	4 065
3	FA width, mm	214
4	Length of the fuel rod active part, mm	3 660
5	Fuel rod outer diameter, mm	9.5
6	Material of spacer grids, mixing grids, an anti-fretting grid and claddings of fuel rods (U-Gd fuel rods)	E110
7	Material of the GT and IT	E635
8	Material of the bottom grid	Stainless steel
10	Fuel assembly burnup, MW*day/kgU	68

TVS-K: Fabrication Capability

PWR fuel

FA assembly is performed on specific stand.

The stand allows to pull fuel rods into bundle with controlled force.

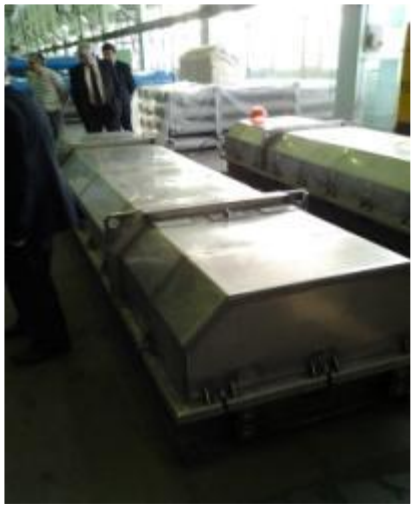


Transportation Capability

PWR fuel

Container	
Length, mm	5080
Width, mm	1262
Height, mm	775
Mass of FFC containing two TVS-K, kg	4000

Loaded fuel	
Q-ty, pcs	2
Flat size, mm	200 … 217
Max. length, mm	4300
Mass of FA not exceeding, kg	800



FFC passed tests for mechanical damage for normal and emergency transportation conditions according to IAEA requirements TS-R-1 (cl.671 – critical mass is excluded for normal, standard and emergency transportation conditions)

Operation Experience & TVS-K Advantages

PWR fuel

The pilot batch of TVS-K fuel assemblies has been loaded in PWR reactor of the Western European utility in June 2014

Technical Advantages:

- Strong skeleton (SG welded to GT) ensures geometrical stability during the operation
- Design of GT with dashpot improves skeleton rigidity
- Exclusion of grid to rod fretting due to original cell-type spring element of TVS-K spacing grid design
- 8-spring (cylindrical) TN holddown system
- E110 and E635 alloys with optimal characteristics of radiation growth, creep, corrosion resistance and hydrating
- TVS-K high burnup up to 68 GWd/tU for flexible fuel cycles and effective fuel consumption
- Reduced hydraulic resistance for better TH performance
- Possibility of core power increase up to 118 percent of Pnom
- 4 FAs are in pilot operation at Western NPP since June 2014

Commercial Advantages:

- Supplies of the bundled FA due to the enrichment capacities availability.
- Possibility of Reprocessed uranium use
- Possibility of the fabrication localization
- 100% TVEL property of design and materials, patented
- There are no limiting agreements with both AREVA and Westinghouse
- «Rosatom» is the one and only, except AREVA, player on the market of nuclear power technologies able to offer the full complex of the services in the field of nuclear fuel cycle.

FC TVEL Quality Management Program

FUEL COMPANY OF ROSATOM
TVEL

Enterprises of JSC «TVEL» were the first in the industry
to be certified for compliance to
ISO 9001:2000 standards of quality

TÜV International Certification
TÜV THÜRINGEN CERT
ISO 9001:2008
15 100 52672
TIC

TÜV International Certification
TÜV THÜRINGEN CERT
ISO 14001:2004
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TÜV International Certification
TÜV THÜRINGEN CERT
OHSAS 18001:2007
15 116 11266
TIC

TÜV CERT

CERTIFICATE

The TÜV CERT Certification Body
of TÜV Thüringen e.V.

certifies in accordance with TÜV CERT
procedure that

Joint Stock Company
"TVEL"
24/26 Bolshaya Ordynka st.
119017 Moscow, Russia
and the subsidiary companies (according to enclosure)

has established and applies a quality management system for

Design, development, production, storage and delivery of fuel assemblies, nuclear reactor core components, fuel assembly materials, semifinished products and components. Production, storage and delivery of nuclear reactor channels. Provision of scientific and technical support services in utilization of fuel assemblies and nuclear reactor core components. Ensuring supplies of material and technical resources.

An audit was performed, Report No. 3330 24W4 D0

Proof has been furnished that the requirements according to

DIN EN ISO 9001:2000

are fulfilled. The certificate is valid until 2010-06-05

Certificate Registration No. 15 100 52672

TÜV THÜRINGEN

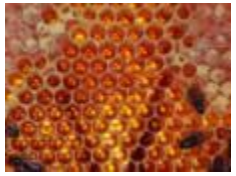
Jena, 2007-06-08

TÜV CERT Certification Body
of TÜV Thüringen e. V.

FC TVEL Environmental Policy

Fuel Company TVEL sees the environmental policy as one of the important competition components. Therefore, every employee in the company enterprises does his/her best in order to work in harmony with nature

TVEL continuously improves environmental programs, works on the development of energy saving technologies, uses natural resources in a cost-efficient way



Corporate system of environmental management of TVEL's subsidiaries has been implemented. Works on the development of the Corporate System of Management of health protection and labour safety corresponding to international standard OHSAS 18001 are going on.

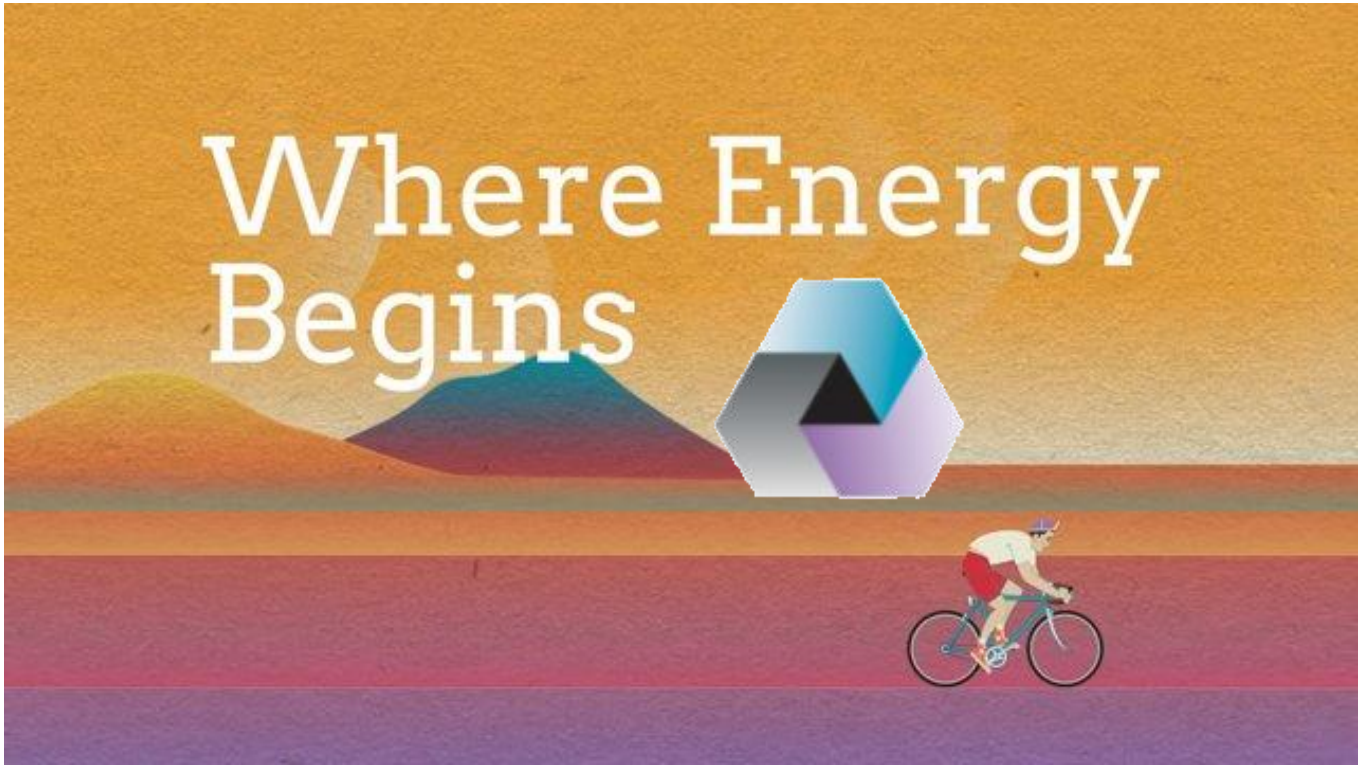
Conclusions

Fuel supply is one of the key questions by development of a new nuclear program

Package supply is optimal for countries starting their national nuclear program

Fuel Company TVEL is integrated into the structure of State Corporation Rosatom and has all the competences to ensure secure supply of safe, reliable and efficient nuclear fuel for both VVER and PWR reactors

Fuel Company TVEL has experience in projects of NF fabrication localization and offers cooperation on wide range of nuclear issues in different formats


Where Energy
Begins