Technology holder perspective on fuel cycle services in international markets: present and future

Alexey Grigoriev
Advisor, JSC TVEL

IAEA,
August, 2012
NFC and Fuel Division
Nuclear Fuel Cycle in Russia

- **Mining & Zr concentrate**
  - Zr Concentrate

- **U raw material**
  - U mining & reprocessing

- **Gaseous centrifuges production**
  - Gaseous centrifuges

- **Conversion & enrichment**
  - Conversion & enrichment

- **NF fabrication**
  - NF fabrication

- **Trading & sale**
  - Trading & sale

- **Nuclear fuel**
  - Nuclear fuel

- **Reprocessed U**
  - Reprocessed U

- **Foreign NPPs**
  - SNF

- **Russian NPPs**
  - SNF

- **UF6 / SWU / EUP**
  - GS export

**TENEX**

*Except uranium mining*
Fuel Division and Fuel Company in the structure of SC “Rosatom”

Fuel Division (FD)

R & D
GC production
Conversion & enrichment
NF fabrication

Transport & logistics assets
Overseas marketing assets

TENEX-Korea Co. (South Korea)
INTEREXCO GmbH. (Germany)
TENEX-Japan Co. (Japan)
TENAM Corporation (USA)
TRADEWILL LIMITED (Great Britain)

SChP
ECP
CMP
MZP

SPb-Isotop
TENEX-Logistics
TENEX-Complect

VNIINM
KMP
Toch mash
MSZ
NCCP

Centrotech-SPb
NRDC
UGS
MP
Ural pribor

EDB-N.Novgorod

AECP
UECP

AEC
UEC

JV with foreign partners
JV in Ukraine

MINING DIVISION

Electric power division

Division, SNF and RW handling

Nuclear Medicine, advanced materials and technologies

Division of Non-core Assets

Division of Non-core Assets

R&D Division

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Global presence

Europe
- France, Germany, Spain, Great Britain, Belgium, Sweden, Finland, Switzerland
- Czech Republic, Hungary, Finland, Ukraine, Slovakia, Armenia, Bulgaria

America
- USA, Mexico

Asia
- South Korea, Japan, China
- Iran, India, China

Africa
- South Africa

Enrichment services (TENEX)
Nuclear fuel and components
Fuel Division. Important player in the NFC world market

17% of NF fabrication world market
40% of uranium enrichment world market

15% of the world fabrication capacities*
22% of the world conversion capacities
45% of the world enrichment capacities

* Only LWR
Product Range

- Uranium Conversion Services
- Uranium Enrichment Services

- Design and production of gaseous centrifuges and auxiliary equipment for uranium isotopes separation

- FA design
- NF components’ production
- FA fabrication for various reactors
# Competences in NF Design & Fabrication

<table>
<thead>
<tr>
<th>Design</th>
<th>Zr- parts</th>
<th>Powder</th>
<th>Pellets</th>
<th>FA</th>
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</thead>
<tbody>
<tr>
<td><strong>VVER</strong></td>
<td><img src="image1" alt="VVER Zr-parts" /></td>
<td><img src="image2" alt="VVER Powder" /></td>
<td><img src="image3" alt="VVER Pellets" /></td>
<td><img src="image4" alt="VVER FA" /></td>
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<tr>
<td><strong>BN, FNPP, etc</strong></td>
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<td><img src="image6" alt="BN, FNPP, etc Powder" /></td>
<td><img src="image7" alt="BN, FNPP, etc Pellets" /></td>
<td><img src="image8" alt="BN, FNPP, etc FA" /></td>
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<td><strong>PWR</strong></td>
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<td><img src="image10" alt="PWR Powder" /></td>
<td><img src="image11" alt="PWR Pellets" /></td>
<td><img src="image12" alt="PWR FA" /></td>
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<tr>
<td><strong>BWR</strong></td>
<td><img src="image13" alt="BWR Zr-parts" /></td>
<td><img src="image14" alt="BWR Powder" /></td>
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<td><img src="image16" alt="BWR FA" /></td>
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<tr>
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<td><img src="image19" alt="PHWR Pellets" /></td>
<td><img src="image20" alt="PHWR FA" /></td>
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* * Within the frames of TVS-K project
** In cooperation with AREVA
Package supply

Utilities are not required to have additional expenses for separate contracts (additional staff, logistic, etc.)

Transfer of price risks for purchase of U, conversion and enrichment to FA supplier

Possibility to receive cumulative discounts

U + conversion + enrichment + fabrication
Quality management

We seek to understand and respect the interests of our clients through meeting their technical and financial expectations at most with our products and services. That is why every contract we make is backed with a package of quality assurance measures, corresponding to the most rigorous international standards.

JSC TVEL enterprises were the first in the industry to be certified for conformance to the international standard ISO 9001:2000. This certification audit was conducted by a high-profile, independent German certification authority, TUV CERT.
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 has been implemented in TVEL’s subsidiaries. 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.
Customer Oriented Approach

Customers' requirements
- Advanced competences in NF performance
- Providing energy security
- Back End solutions
- Reliability of nuclear fuel
- Reactor up rate
- Extended fuel cycle
- Maneuvering modes
- FA reparable
- NFC localization
- Technological independence
- Reactor up rate

TVEL’s proposals
- Significant scientific potential
- Establishment of a regional plant
- Package proposal (NF + NFC back end services)

Fuel Company TVEL
Back End of Nuclear Fuel Cycle
Russia’s Back End competence

**STORAGE**

- Storage of irradiated VVER-1000, RBMK fuel assemblies for further reprocessing

**SNF REPROCESSING**

- Reprocessing of irradiated fuel assemblies from:
  - NPPs with reactors:
    - VVER-440,
    - BN-600,
  - Propulsion nuclear reactors
  - Research reactors

**NF FABRICATION FROM REPROCESSED PRODUCTS**

- NF fabrication from RepU for reactors:
  - PWR,
  - BWR
  - RBMK
  - VVER
RUSSIAN NPP FLEET – 24,24 GWt (e), 10 NPP

VVER-440 – 6 units in operation until 2030, 2 units under decommissioning

Other LWRs and FRs in operation:

VVER-1000 – 10 units in operation, 11 units under construction

RBMK-1000 – 11 units in operation

FBRs: BN-600 – 1 unit in operation, BN-800 – one unit under construction
BN-1200 – deployment of 1-3 units is planned for 2020-2030

EGP-6 in Bilibino – 4 units in operation, decommissioning is planned for 2018-2021
Floating NPP is considered for replacement
SNF accumulation in Russia

Accumulated SNF on 01.01.2011 – total 22 079 t HM,

SNF locations

**VVER-1000**- 86% at centralized wet storage at MCC, 14% at NPP

**RBMK-1000** – about 100% at NPP

SNF generation

**VVER-1000** ~ 200 t/y

**RBMK-1000** ~ 400 t/y
Current situation with SNF in Russia

Accumulated SNF on 01.01.2011 – total 22 079 t HM, including:

- at NPP – 16 314 t HM
- at centralized storage – 5 765 t HM

Discharge of SNF at NPP

Transportation for centralized storage and reprocessing

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge SNF at NPP</th>
<th>Transportation for centralized storage and reprocessing</th>
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<tr>
<td>2011</td>
<td>650</td>
<td>270</td>
</tr>
<tr>
<td>2015</td>
<td>1050</td>
<td>695</td>
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Temporary storage SNF at NPP

SNF reprocessing

SNF arrangement for centralized long-term “dry” storage
RT 1 (PO “MAYAK” site)

Design capacity - 400 t/y, now reprocessing up to 100 - 120 t/y SNF of VVER-440, BN - 600, submarine, RR.

The reprocessing process - “modified purex”

The products are: uranil nitrate hexahydrate enriched up to 2.6 % $\text{U}_{235}$ for the fabrication of fuel for RBMK-1000. Re-enrichment is achieved by blending the purified uranyl nitrate solutions resulting from reprocessing of different spent fuel types with different uranium enrichment levels (BN, RRs, propulsion reactors fuels and VVER fuel);

uranium oxides with $\text{U}_{235}$ enrichment of 17 %;

neptunium dioxide (is used for production of $\text{Pu}_{238}$ isotope);

plutonium dioxide (in a special packages is transferred for storage).

In medium-term – in addition reprocessing ‘problem’ type of SNF (EGP, damaged RBMK)

2011 – first transportation from Leningrad NPP and reprocessing at Mayak plant of damaged RBMK fuel
Technological strategies for SNF management – storage and reprocessing

- **VVER-1000 (1200)**
  - Centralized Storage at MCC

- **VVER-440, BN-600, RR fuel, Subs Fuel, Legacy Fuel**
  - Reprocessing at RT 1 Mayak
    - 5%

- **RBMK-1000**
  - Centralized Storage at MCC
    - 95%
  - Reprocessing

- **Currently non-processed fuel (EGP)**
  - Reprocessing

- **Civil Pu consumption**

- **RT-2 Deployment**

- **HLW Final Disposal**

- **Operation of RT-1 until 2030**

- **Reprocessed U consumption**

- **On Site Disposal**

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Modernization of RW management system on PO “MAYAK”

Vitrification complex – new furnace EP-500/5 and new storage for vitrified HLW

Complex of cementation of ILW – capacity 5,5 thousand cubic meter/year storage for 28 thousand cubic meter

LLW treatment facility – 150 thousand cubic meter ILW & LLW/y

View of the cementation complex
SNF management cluster at MCC

- **ХОТ-1** - Wet storage for VVER-1000;
- **ХОТ-2** - Dry storage for VVER-1000 and RBMK SNF;
- **ОДЦ** - Test demonstration center for reprocessing technology developing (further - large scale reprocessing plant);
- Underground laboratory (further - Deep geological disposal site for HLW)
“Dry” centralized storage

2010 – construction works at start-up complex are completed
2011 – commissioning of start-up complex for 9200 t SNF RBMK
2012 – the first delivery of RBMK SNF
The first delivery RBMK SNF at MCC

On April 5, 2012 at MCC the first train arrived with SNF RBMK-1000 from the Leningrad NPP.

On April 11, 2012 cases with SNF RBMK-1000 are established on long-term storage in "dry" storage.
“Dry” Vault-type Storage for RBMK fuel

1 – storing seat;
2 – case with gas (N₂+He₂);
3 – fuel element of assembly
## Parameters of “dry” storage

<table>
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<tr>
<th>Parameter</th>
<th>RBMK-1000</th>
<th>VVER-1000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooling environment</strong></td>
<td>Outer air</td>
<td>Outer air</td>
</tr>
<tr>
<td><strong>Storing environment</strong></td>
<td>(N_2+\text{He}_2)</td>
<td>(N_2+\text{He}_2)</td>
</tr>
<tr>
<td><strong>Outside air temperature, °C</strong></td>
<td>+38</td>
<td>+38</td>
</tr>
<tr>
<td><strong>Air temperature at the chamber outlet, °C</strong></td>
<td>+94</td>
<td>+94</td>
</tr>
<tr>
<td><strong>Temperature at the surface of storing seat, °C</strong></td>
<td>+145</td>
<td>+147</td>
</tr>
<tr>
<td><strong>Maximum temperature of the fuel element cladding, °C</strong></td>
<td>+248</td>
<td>+308</td>
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“Wet” storage reconstruction

Reconstruction improvements were made 3 years before Fukushima accident:

- Anti-seismic stability forced;
- Four cranes replaced;
- More effective cooling system.

Results of the works implemented:

- Storage capacity increases by 2600 tons of SNF (from 6000 t up to 8600 t);
- Storage operation life expands up to 15÷20 years minimum.
Creation the test demonstration center – basic element of spent nuclear fuel management system

• Since 2008 wide spectrum of R&D activities with real fuel was performed;
• Preliminary designs for new technological equipment developed;
• TDC conceptual design developed and approved;
• Detailed design activities are go on, cold testing of equipment prototype are in progress.

Developing of economy-type and environmentally friendly reprocessing technology, lack of LRW discharges, minimization of HLW for disposal
The basic technology SNF reprocessing complex
capacity 100 t/y (further – up to 250), full cycle SNF reprocessing, products – $U_3O_8$ and mixed oxides U-Pu-Np; waste – concrete for medium level waste, borosilicate vitrified HLW

Hot cells complex for research innovation technological processes and equipments.
One module capacity is 2-5 t/y.
Analytical laboratory for control composition of technological stream and products «Cold» facility for full scale test of new technological equipments
Deep geological disposal site for HLW (Krasnoyarsky Kray, Nizhnekeanskii massife)

Strategic project of priority – construction of primary final RW isolation objects (Krasnoyarsky Kray).

Creation objective: ecologically safe, technically robust and economically acceptable final isolation of the most hazardous RW, accumulated in Russia, e.g. during the military program execution.

Activities in 2011

Pre-project stage of HLW disposal site has been carried out;

Assessment of HLW disposal site impact to environment was developed and is prepared for discussion with the community;

Plan of design realization is approved (beginning is planned in 2012);

Public discussion on disposal site is planned to start in 2012.
The program of SNF management infrastructure creation up to 2030 is approved by ROSATOM in 2011.
Complex proposal: NF + Back End services
Pay and Forget

Russia

Partner state

Provide service “pay and forget”

Utility

Economic factors

Political factors

Environmental factors
Main advantages of package proposal

**Economic advantages**
- cost of services (due to scale effect)
- discounts for Front End NFC due to connected Back End contracts
- industry’s economic efficiency

**Political advantages**
- demonstration of commitment to nonproliferation
- demonstration of readiness to international cooperation and commitment to nuclear safety assurance

**Environmental advantages**
- SNF and RW disposal
- no SNF storage in the area where NPP is located
- lesser number of ecologically hazardous manufacturing facilities in the territory of partner states

Package proposal: NF + Back End services
- NF fabrication from natural uranium
- NF fabrication from RepU/MOX
- SNF storage and reprocessing
- RW final disposal
  - Repository
  - BN reactor
  - Other technology
Russia is the only state in the world that may not return RW to utility if fresh nuclear fuel was fabricated on the Russian territory.
Outsourcing of SNF reprocessing and disposal in the RF will allow to avoid the need of domestic Back End infrastructure establishment.

- nuclear industry in the countries – partners of the RF becomes more environmentally friendly
- no potentially hazardous manufacturing facilities
Facilitation of the dialogue with world community

Cooperation with RF in the field of Back End

Strict observance of International regulations and agreements

High standard in the nuclear field

Demonstration of readiness for mutual cooperation

No need for development of domestic Back End infrastructure

Demonstration of peaceful trend of nuclear industry development program

Lifting of some barriers for implementation of nuclear industry development program by world community
Lower services’ costs due to the scale effect

Growth of installed capacity of Russian NPPs
GWt, basic scenario

- Rosatom scenario before Fukushima
- Rosatom scenario after Fukushima

Despite Fukushima accident Russia maintained plans for nuclear generation buildup.

Creation of Back End Infrastructure necessary to satisfy the RF domestic needs, as minimum

Reduction of the Back End cost for both Russian enterprises and foreign partners

Reduction of costs of SNF and RW management due to scale effect
Creation of new Back End infrastructure based on state-of-the-art technologies

- High economic parameters of new technologies will positively affect Russian Back End services prices
- Unique technological solution that take into account accumulated Russian and foreign experience
- Fundamental knowledge and significant experience in SNF and RW management
Discounts for Front End services due to system of connected contracts for Front End and Back End services. This will improve utilities’ economy.

This is achieved by guaranteed work load of Russian enterprises of all NFC stages, giving more room for maneuvering due to redistribution of cash flows inside Russian nuclear industry.
SNF recycling

SNF management cost compensation due to RepU and Pu recycling.
Discounts due to utilization of products of SNF reprocessing in the RF

Russia

Partner state

Procurement of products of SNF reprocessing, which can be used for fuel manufacturing

Back End services

Utilities are not interested in use of products of SNF reprocessing

Utilities

Cheaper services for customers through discounts given by the Russian Party equal to the cost of uranium component of products of SNF reprocessing that can be utilized
Thank you for your attention!