THE VVER 1200
DELIVERED BY ROSATOM

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New nuclear power in the Netherlands beyond 2030
Universiteit Twente
October/29/2021
ROSATOM AT A GLANCE

138.3 Bn USD
10-YEAR PORTFOLIO OF OVERSEAS ORDERS

16.7 Bn USD
REVENUE*

35 UNITS
OVERSEAS NPP PORTFOLIO

RUSSIAN DESIGNED NPPs AVOIDED
213 M tonnes of CO₂eq

0 INES
LEVEL-2 INCIDENTS
36 UNITS (31 GW)

R&D INVESTMENT
4.5% of revenue

GLOBAL FOOTPRINT -
> 50 countries

>250 000
EMPLOYEES

* Source: Rosatom IFRS, annual report
ROSATOM: ALL THAT IS NUCLEAR

ENERGY SECTOR

U-235

Enrichment & conversion

Uranium mining

Fuel fabrication

Equipment manufacturing

NPP design, engineering & construction

NPP operation & maintenance

Back end

NON-ENERGY SECTOR

Nuclear medicine

Gamma irradiation

Research reactors

Isotope products

Applied science

Nuclear icebreaker fleet

CNST
CONTRIBUTION TO CLIMATE SAVING

33.3
M hectares of forest
WILL ABSORB THE SAME AMOUNT OF CO₂ IN A YEAR

11% OF FOREST AREA IN THE USA &
3 TIMES MORE THAN TOTAL FOREST AREA IN GERMANY

ALL RUSSIAN–DESIGNED NPPs SAVE:

213
M TONNES CO₂eq on average per year

108 M TONNES CO₂eq DOMESTIC +
105 M TONNES CO₂eq ABROAD
FINANCIAL SUSTAINABILITY

**Revenue**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td></td>
<td>16.6</td>
<td>16.1</td>
<td>13.5</td>
<td>12.9</td>
<td>16.6</td>
<td>16.5</td>
<td>17.8</td>
<td>16.7</td>
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</tbody>
</table>

*Source: Rosatom IFRS, annual report*

**Consistent Profitability Margins**

<table>
<thead>
<tr>
<th>Year</th>
<th>EBITDA</th>
<th>EBITDA margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>35%</td>
<td>44%</td>
</tr>
<tr>
<td>2014</td>
<td>41%</td>
<td>36%</td>
</tr>
<tr>
<td>2015</td>
<td>39%</td>
<td>31%</td>
</tr>
<tr>
<td>2016</td>
<td>31%</td>
<td>41%</td>
</tr>
<tr>
<td>2017</td>
<td>41%</td>
<td>37%</td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
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</tbody>
</table>

*Source: AEP IFRS, annual report*

**Overseas revenue**

<table>
<thead>
<tr>
<th>Year</th>
<th>Bn USD</th>
<th>2011</th>
<th>2014</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td></td>
<td>4.8</td>
<td>5.2</td>
<td>7.5</td>
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</table>

**Credit Ratings**

<table>
<thead>
<tr>
<th></th>
<th>S&amp;P</th>
<th>Fitch Ratings</th>
<th>Moody’s Investors Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating</td>
<td>BBB-/A-3</td>
<td>BBB</td>
<td>Baa3</td>
</tr>
<tr>
<td>Forecast</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
</tr>
</tbody>
</table>

*Source: Rosatom IFRS, annual report*
"ROSATOM – BEING LOCAL GLOBALLY"

**REGIONAL & COUNTRY CENTERS**

- EASTERN EUROPE*
- CENTRAL EUROPE
- WESTERN EUROPE*
- MIDDLE EAST AND NORTH AFRICA*
- CENTRAL AND SOUTH AFRICA
- SOUTH ASIA*
- SOUTH-EAST ASIA*
- EAST ASIA*
- RUSSIAN FEDERATION

**FOREIGN REPRESENTATIVES**

- Acting Rosatom foreign representatives at Russian Embassies, Trade Missions and Permanent Missions of the Russian Federation to the IO in Vienna and to the EU and EAEC in Brussels: Austria, Argentina, Armenia, Bangladesh, Belarus, Belgium, Vietnam, Egypt, India, Iran, Kazakhstan, China, Turkey, Uzbekistan and Japan

*Regional Centers

*Country Centers
SECOND NUCLEAR UTILITY GLOBALLY

36 UNITS in operation at 10 NPPs

1 FPU AKADEMIK LOMONOSOV FNPP

30,58 GWe total installed capacity (as of July 01, 2021)

20,3% nuclear in Russian power generation mix in 2020

NPP power generation in Russia

Generation dynamics, TW–h

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW–h</td>
<td>195.2</td>
<td>196.4</td>
<td>202.9</td>
<td>204.3</td>
<td>208.8</td>
<td>215.7</td>
</tr>
</tbody>
</table>

Technologies in operations portfolio

Installed capacity, GWe

- VVER — 18,798
- KLT — 0.070
- EGP — 0.036
- BN — 1,485
- RBMK — 9.0
TOP-10 NUCLEAR POWER INNOVATION LEADER
(according to Thomson Reuters)

WORLD’S ONLY FLOATING NPP
SMR technology is widely referenced by the icebreaker fleet
More than 400 REACTOR YEARS!
Supply of electricity, thermal power and desalinated water to isolated territories

FAST NEUTRON REACTORS
The BN type reactor is a breakthrough generation IV nuclear energy system
More than 40 YEARS of safe operation!
Increased fuel base, allows closed fuel cycle
## MODERN SMR SOLUTIONS

<table>
<thead>
<tr>
<th>Floating NPP</th>
<th>Land-based solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical capacity</strong></td>
<td>100 MW</td>
</tr>
<tr>
<td><strong>Refueling cycle</strong></td>
<td>up to 10 years</td>
</tr>
<tr>
<td><strong>Design life</strong></td>
<td>60 years</td>
</tr>
<tr>
<td><strong>Displacement</strong></td>
<td>16 680 tons</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>112 m</td>
</tr>
<tr>
<td><strong>Beam</strong></td>
<td>30 m</td>
</tr>
</tbody>
</table>
DIVERSIFIED URANIUM RESERVES

No2 in Uranium reserves globally (696 th. tU)

No2 in Uranium production globally

15% of all global production in 2020

100% of Uranium abroad was mined by ISL mining technology

PRODUCTION & DEVELOPING PROJECTS

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100% of Uranium abroad was mined by ISL mining technology

Uranium production

Tonnes U

In Russia

Abroad

2017

2018

2019

2020

8 019

5 102

2 917

4 385

7 289

4 385

2 904

4 617

7 528

4 617

2 911

4 276

7 122

4 276

2 846

SUPPLY GEOGRAPHY

EUROPE

NORTH & SOUTH AMERICA

ASIA

Mining projects

Exploration projects
URANIUM CONVERSION & ENRICHMENT LEADER

No1 in installed capacities

~1/3 of global uranium enrichment market

50 years of centrifuge technology development

GEOGRAPHY OF SUPPLY & PRODUCTION FACILITIES

- Mexico
- South Korea
- UAE
- China
- Japan
- Canada
- Belgium
- United Kingdom
- France
- Spain
- Switzerland
- Germany
- Ukraine
- Sweden
- Russia
- Kazakhstan
- Finland

10-Year portfolio of overseas orders

Bn USD

<table>
<thead>
<tr>
<th>Year</th>
<th>Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>17</td>
</tr>
<tr>
<td>2018</td>
<td>16</td>
</tr>
<tr>
<td>2019</td>
<td>15</td>
</tr>
<tr>
<td>2020</td>
<td>18</td>
</tr>
</tbody>
</table>
KEY PLAYER ON THE GLOBAL FUEL MARKET

17% global NPP fuel market share

> 70 power units work on Rosatom fuel

> 10 countries supplied with research reactor fuel

Fuel assemblies, U and Zr fuel components

new fuel
- tolerant fuel testing
- MOX-fuel for fast reactor
- fuel from reprocessed uranium

Advanced technologies for increased safety & fuel performance in open and closed fuel cycle

10-Year portfolio of overseas orders

<table>
<thead>
<tr>
<th>Year</th>
<th>Bn USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>10</td>
</tr>
<tr>
<td>2017</td>
<td>11</td>
</tr>
<tr>
<td>2018</td>
<td>13</td>
</tr>
<tr>
<td>2019</td>
<td>14</td>
</tr>
<tr>
<td>2020</td>
<td>16</td>
</tr>
</tbody>
</table>

GEOGRAPHY OF SUPPLY & PRODUCTION FACILITIES
EXTENSIVE MANUFACTURING CAPABILITIES

>20 countries use Rosatom equipment

3-4 sets of nuclear steam supply systems annual capacity

>20 enterprises in Russia and abroad

PRODUCTION FACILITIES

<table>
<thead>
<tr>
<th>Country</th>
<th>Facility Type</th>
<th>Manufacturer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saint-Petersburg</td>
<td>Engineering Unit, pumps - CDBMB, NPP turbine island equipment - AEM</td>
<td></td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Valves - ARAKO</td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>Pumps, hydropower turbines - GANZ</td>
<td></td>
</tr>
<tr>
<td>Ukraine</td>
<td>Castings and forgings - EMSS</td>
<td></td>
</tr>
<tr>
<td>Petrozavodsk</td>
<td>Reactor equipment - AEM-t</td>
<td></td>
</tr>
<tr>
<td>Nizhny Novgorod</td>
<td>Design &amp; Engineering, Fast Neutron reactors, Low &amp; medium power reactors, Pumps &amp; LNG equipment - OKBM</td>
<td></td>
</tr>
<tr>
<td>Volgodonsk</td>
<td>Nuclear steam supply system equipment - AEM-t</td>
<td></td>
</tr>
<tr>
<td>Podolsk</td>
<td>Reactor vessel equipment - ZIO-Podolsk, Design &amp; Engineering - OKB «GIDROPRESS»</td>
<td></td>
</tr>
</tbody>
</table>
NPP OPERATION & MAINTENANCE THROUGHOUT THE WHOLE LIFE CYCLE

- **27** units in service
- **10** countries with operations
- **№1** on VVER market

**GEOGRAPHY OF PROJECTS**

Countries: Finland, Bulgaria, Hungary, Slovakia, Egypt, Armenia, India, Bangladesh, Turkey, China

**KEY SERVICES**

- NPP & CNST INFRASTRUCTURE DEVELOPMENT
- PERSONNEL TRAINING
- MODELING AND SIMULATION
- NPP COMMISSIONING
- NPP OPERATION & MAINTENANCE

**10-Year portfolio of overseas orders**

- 2016: 418 M USD
- 2017: 1,045 M USD
- 2018: 1,862 M USD
- 2019: 1,903 M USD
- 2020: 2,093 M USD
RELIABLE SPENT NUCLEAR FUEL MANAGEMENT

17 countries sent NPP & RR SNF back to Russia for reprocessing

ALL SNF types can be reprocessed

The 1st fast neutron reactor loaded with MOX fuel in the world

KEY SERVICES (present & under development)

- SNF / HLW storage and transportation casks
  - SNF/HLW storage and/or transportation casks design and supply
  - Interim SNF storage in Russia
  - SNF packaging and transportation (incl. air shipment for RR SNF)

- SNF reprocessing with HLW partitioning
  - SNF radiochemical reprocessing recovering RepU and Pu
  - HLW partitioning (Cs-Sr separation)
  - HLW conditioning in compliance with customer’s requirements
  - Adaptation of customer’s infrastructure for HLW disposal

- RepU and Pu Fuel

- RepU and Pu recycling in fresh fuel both for LWRs & fast reactors
## UNIQUE COMPETENCIES IN DECOMMISSIONING AND RADIOACTIVE WASTE MANAGEMENT

<table>
<thead>
<tr>
<th>&gt; 50 YEARS OF PRACTICAL EXPERIENCE</th>
<th>ANY FACILITIES</th>
<th>TURNKEY ROSATOM PROVIDES ALL TYPES OF WORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGINEERING SERVICES (DESIGN AND ENGINEERING)</td>
<td>DEACTIVATION, DISMANTLING AND DISASSEMBLY OF EQUIPMENT AND STRUCTURES</td>
<td>RW MANAGEMENT</td>
</tr>
</tbody>
</table>

- Developing decommissioning strategies and concepts
- Performing site surveys
- Developing design documents
- Preparing licensing documents

- Removal of nuclear products and SNF
- Deactivation
- Dismantling of equipment, systems, and civil structures
- Rehabilitation and restoration of lands

- RW removal and separation
- RW processing, storage, and transportation
- RW characterization, conditioning, and passportization
- RW disposal in repositories
NUCLEAR INDUSTRY PIONEER

ROSATOM HISTORICAL MISSION AS THE PIONEER IN NUCLEAR ENERGY – TO PROVIDE FOREIGN PARTNERS WITH ALL-ENCOMPASSING SUPPORT IN SUSTAINABLE DEVELOPMENT OF THE REGION

First NPP ever constructed

- **OBNINSK**
  - 48 YEARS of successful operations
  - 1954

First research reactor built overseas

- **BUCHAREST**
  - Operation began in 1957

First NPP ever built by vendor overseas

- **BOHUNICE**
  - Construction began in 1958

First VVER NPP built overseas

- **RHEINSBERG**
  - Construction began in 1960
IMPRESSIVE PORTFOLIO OF SUCCESSFUL PROJECTS

106
RUSSIAN-DESIGNED NPP UNITS HAVE BEEN BUILT GLOBALLY

OF WHICH
80 VVER NPP UNITS
THE ONLY COMPANY IMPLEMENTING SERIAL NPP CONSTRUCTION GLOBALLY

17 NPP UNITS IN 15 YEARS CONNECTED TO THE GRID

Tianwan-1
Rostov-2
Kalinin-4
Rostov-3
Kudankulam-2
Rostov-4
Novovoronezh 2-2
Belarus-1

2006
2007
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

Tianwan-2
Busher-1
Kudankulam-1
Beloyarsk-4
Novovoronezh 2-1
Tianwan-3
Leningrad 2-1
Leningrad 2-2

NPP construction abroad
NPP construction in Russia
ADVANCED GENERATION III+ NUCLEAR TECHNOLOGY

VVER–1200* – FUSION OF TECHNOLOGICAL HERITAGE AND INNOVATION

ADVANCED PWR TECHNOLOGY
meets all the IAEA safety standards and requirements

*in commercial operation since Feb, 2017

1st
1200 MWe
60+ years
> 90%
1500
Active & Passive
combination of safety systems

gen III+ reactor in operation
nominal output
lifecycle
availability factor
reactor years of safe operation

REV
REIN ROGATON

nominal output
lifecycle
availability factor
reactor years of safe operation

comb.
### VVER 1200 – Some Key Figures

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Thermal Power</td>
<td>3200 MW</td>
</tr>
<tr>
<td>Nominal Electrical Power</td>
<td>1198 MW</td>
</tr>
<tr>
<td>Efficiency (gross)</td>
<td>37.5 %</td>
</tr>
<tr>
<td>Primary system pressure (nom/design)</td>
<td>16.2 / 17.6 MPa</td>
</tr>
<tr>
<td>Coolant Temperature (inlet/outlet)</td>
<td>298 / 329 °C</td>
</tr>
<tr>
<td>Steam Pressure at SG outlet</td>
<td>7.9 MPa</td>
</tr>
<tr>
<td>Active Safety Trains</td>
<td>4x100% / 4x50% 1)</td>
</tr>
<tr>
<td>Design Lifetime</td>
<td>60 years</td>
</tr>
<tr>
<td>Containment</td>
<td>Double</td>
</tr>
<tr>
<td>Autonomy after accident</td>
<td>&gt;72 hours</td>
</tr>
<tr>
<td>Number of FA / RCCA</td>
<td>163 / 121</td>
</tr>
<tr>
<td>Mass of UO$_2$ in the core</td>
<td>87065 kg</td>
</tr>
<tr>
<td>Operational Cycle</td>
<td>12 / 18 months</td>
</tr>
<tr>
<td>Airplan Crash (Design Basis / DEC)</td>
<td>Small / commercial</td>
</tr>
</tbody>
</table>

1) Emergency Boron Injection System
VVER 1200 - a 4-loop Pressurized Water Reactor
## Evolution of designs from VVER-1000 to VVER-1200

<table>
<thead>
<tr>
<th>VVER-1000 RU V-320</th>
<th>VVER-1000 RU V-428 (AES-91)</th>
<th>VVER-1000 RU V-466 (VVER-91/99)</th>
<th>VVER-1200 RU V-491</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Russian design</td>
<td>Improved safety design with increased technical and economic parameters</td>
<td>Design complying with modern European and International standards (EUR and YVL)</td>
<td>Serial design satisfying modern Russian, European and International requirements for new NPPs</td>
</tr>
<tr>
<td>Implemented in NPPs in Russia, Ukraine, Bulgaria, Czech Republic</td>
<td>Developed for Finland Implemented at Tianwan NPP (China)</td>
<td>Bid for FIN5 NPP in 2003</td>
<td>Leningrad NPP-2 (LNPP-2) Belarus NPP, Baltic NPP Hanhikivi 1, Paks, El Daaba</td>
</tr>
</tbody>
</table>

**Lovisa**

- VVER-640
- Passive safety, Medium power

**Timeline**

- **1970s**
- **1980s**
- **1990s**
- **2000s**
- **2010s**
Selected Inherent Safety Features

- Negative coefficients of reactivity;
- Considerable coolant inventory in the primary circuit;
- Horizontal steam generators;
- SG tubes are made of stainless steel;
- Considerable water inventory in steam generator secondary side;
- Extensive use of passive components and systems;
- the core is made up of hexagonal fuel assemblies;
- RPV without longitudinal welds;
- No penetrations in the reactor bottom;
- Two-lines arrangement of the RPV nozzles.
Diverse and redundant safety systems

The leading philosophy in the design of the VVER 1200 plants is:

All fundamental safety functions shall be provided both with
• active systems that have very reliable AC power supply and
• passive systems that do not need electrical power at all

This gives the operators a possibility to use different safety systems independently of each other and in a flexible manner, depending on the accident scenario.
Double Containment

- **Inner containment**
  - prestressed reinforced concrete
  - 1.2 meters in cylindrical part
  - Inner surface with 6 mm welded steel liner.

- **Outer containment**
  - Reinforced concrete up to 2.2 meters thick in cylindrical part

- **Annulus**
  - 1.8 meters gap
  - Maintenance of negative pressure
  - Filtered ventilation to atmosphere

- **All process penetrations with isolation valves**
Containment of Radioactive Materials after a Severe Accident (hypothetical)

The target for protecting the reactor containment after a possible core meltdown accident was set in the USSR soon after the Chernobyl accident.

All European nuclear regulators agreed in 2010 that this target has to be met by all new NPPs in Europe.

After Fukushima Daiichi accident, this target has received worldwide support.

Installation of the shell of the core catcher
Core Catcher

- Failure of active and passive cooling systems could result in fuel melting and destruction of the reactor pressure vessel.
- Is placed below the reactor vessel to protect the containment against impact of molten core (\( T >> 2000^\circ C \)), eliminating generation on non-condensable gases, including hydrogen and carbon monoxide.
- Adds neutron absorbers to the melt and maintains long-term sub-criticality.
- Transfers passively the heat to cooling water surrounding the “core melt pot” and ensures long term cooling and solidification of the molten core.
- Eliminates the need to vent the containment in the recovery stage.
1st Core Catcher in the World – Tianwan 2007
Passive core cooling after loss of coolant accident
Two Stages provide additional safety margin

The **1st stage Hydro Accumulators** are fast flooding of the reactor core during large-break leaks. The system operates automatically when the pressure in the reactor coolant system drops below 5.9 Mpa.

The **2nd stage Hydro Accumulators** are passively flooding the reactor core in an emergency with boric acid solution. The system operates automatically when the pressure in the reactor coolant system drops below 1.5 Mpa. It will keep the fuel covered with water for at least 24 hours after the largest possible pipe break without operator intervention.
The Additional Layer of Safety
Passive Heat Removal Systems (PHRS)

• Boiling off water from the Emergency Heat Removal Tank (EHRT) to the atmosphere.

• PHRS-SG: Provide fuel cooling via the SG during station blackout, loss of feedwater, small-break LOCA (BDBA).

• C-PHRS: Long-term heat removal from the containment in case of any BDBA / SA.

• Dedicated self-standing system for refilling EHRT from large condensate tanks inside protected buildings or via mobile equipment.
Passive containment overpressure protection system of VVER-1200

- No valves in cooling loops; circulation starts by gravitation if containment temperature increases.
- Capacity 4x33% increasing during event propagation.
- Cooling tanks adequate for 72 h operation without intervention.
Steam Generator PHRS

- Prevention of fuel damage by passive cooling in case of BDBA, with loss of active cooling systems.
- Steam from the secondary side of the steam generators condenses in the EHRT.
- Condensate drains back to the SG by gravity.

1 – emergency heat removal tanks (EHRT) outside containment; 2 – steam lines; 3 – condensate pipelines; 4 – SG-PHRS valves
[5 – heat exchangers of containment]; 6 – steam generators; 7 – cutoff valves
Containment Protection during Severe Accidents (hypothetical)

- Reactions of the molten core create hydrogen inside the containment and increase the risk of hydrogen explosions and subsequent containment failure.
- Passive catalytic recombiners maintain hydrogen concentration below the explosion threshold.
- Location of recombiners is based on detailed computer modelling.
In the first days and weeks after a severe accident, the release of radioactive iodine would cause the largest radiological risk to the people living in the neighborhood.

Today’s VVER containments are equipped with a system that chemically binds the iodine released inside the containment. This reduces the risk of radioactive releases from the containment.
Summary: Diverse and Redundant safety systems

- All fundamental safety functions are ensured by multiple different safety systems, both active and passive;
- All new VVER plants incorporate design features that take properly into account the main "Fukushima issues":
  - Long term cooling of reactor core without electrical power
  - Long term decay heat removal, not relying on primary ultimate heat sink (sea, river, cooling tower, ...) and
  - Protection of reactor containment integrity with dedicated systems after a potential core meltdown accident.
- The VVER design incorporated most of these safety features long before the Fukushima Daiichi incident.
Reactor Pressure Vessel - Integrity For At Least 60 Years

• Enhanced RPV materials and structure
  - less impurities in base metal and welds, less nickel in welds, increased vessel diameter in order to reduce neutron irradiation of the vessel;
  - extensive research and testing, certified to $6.4 \times 10^{19}$ neutr/cm$^2$ (0.5 MeV);
  - improved location of welds in the core area;
  - improved number and location of irradiation samples.

• No Bottom penetrations
Steam Generators – Model PGV1200

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design pressure (secondary)</td>
<td>9,0 Mpa</td>
</tr>
<tr>
<td>Steam capacity</td>
<td>1502 t/hr</td>
</tr>
<tr>
<td>Feedwater temperature</td>
<td>225 °C</td>
</tr>
<tr>
<td>Heat exchange surface</td>
<td>6.105 m²</td>
</tr>
<tr>
<td>Number of tubes</td>
<td>10,978</td>
</tr>
<tr>
<td>Size of tubes</td>
<td>16 x 1.5 mm</td>
</tr>
<tr>
<td>Vessel Length</td>
<td>14,020 mm</td>
</tr>
<tr>
<td>Vessel Diameter</td>
<td>4,200 mm</td>
</tr>
<tr>
<td>Total mass</td>
<td>330 t</td>
</tr>
<tr>
<td>Secondary water volume</td>
<td>63 m³</td>
</tr>
<tr>
<td>Continuous blow-down</td>
<td>20 t/hr</td>
</tr>
</tbody>
</table>
Horizontal Steam Generators – The Superior Choice

• Enhanced resistance to dynamic loads;
• Reduced need for height of reactor building facilitates seismic design of containment;
• Continued primary recirculation in case of loss of coolant accidents;
• Larger water inventory, increased time to mitigate feedwater problems;
• Larger steam evaporation surface reduces steam velocity;
• Low steam velocity reduces tube vibration and eliminates tube fretting;
• Low steam velocity eliminates need for sophisticated steam dryers,
• Using the right tube material: «08X18H10T» steel (equiv. AISI 321) with ~10% Ni reduces primary and secondary SCC;
• Absence of tube-sheet substantially reduces fouling or denting;
• Superior water chemistry virtually eliminates inner bundle fouling or denting.
Main Circulating Pumps (MCP) – State of the Art

SPECIAL DESIGN FEATURES OF MCPs:

• Main circulating pump hydraulic and electrical part bearing are water cooled and water lubricated that reduces risk of oil fire inside containment.

• Optimized Stand-still seals reducing the leakage to less than 200 liters per day in case of loss of electricity.

• Reactor cooling piping is designed in compliance with the “LEAK BEFORE BREAK” concept.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>22,600 m³/hr</td>
</tr>
<tr>
<td><strong>Head</strong></td>
<td>0.624 MPa</td>
</tr>
<tr>
<td><strong>Coolant Temperature</strong></td>
<td>298 °C</td>
</tr>
<tr>
<td><strong>Intake Pressure (nominal)</strong></td>
<td>16 MPa</td>
</tr>
<tr>
<td><strong>Rotational Speed</strong></td>
<td>1000 rpm</td>
</tr>
</tbody>
</table>
Why Hexagonal Fuel?
More fuel in active zone compared to square arrangement;
More efficient fuel cooling compared to square arrangement;
Increased rigidity eliminates the “banana fuel” effect known to square arrangement;
Criticality risk during transport and storage accidents is virtually eliminated.

**FUEL & CORE DESIGN**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Assembly Height</td>
<td>4570 mm</td>
</tr>
<tr>
<td>Fuel Rods per FA</td>
<td>312</td>
</tr>
<tr>
<td>Fuel Rod Pitch</td>
<td>12.75 mm</td>
</tr>
<tr>
<td>Mass of FA</td>
<td>750 kg</td>
</tr>
<tr>
<td>Mass of UO₂ in FA</td>
<td>534.1 kg</td>
</tr>
<tr>
<td>Maximum burn-up (achieved)</td>
<td>59.14 MW·day/kgU</td>
</tr>
<tr>
<td>RCCA – drop time</td>
<td>&lt; 2.5 sec</td>
</tr>
</tbody>
</table>
Superior Reactivity control

IF THE CONTROL RODS ARE INSERTED IN THE CORE THE REACTOR WILL STAY IN SHUTDOWN STATE EVEN AT LOW TEMPERATURE.

- This has been achieved by increased number of control rods and by their high effectiveness in capturing neutrons.
- It is not necessary to add boron to the coolant for ensuring long term safe cold shutdown. However, there is an option to release liquid with high boron concentration to coolant from passive pressurized hydro-accumulators during the cooling and depressurization (deep shutdown by rods permits cooling, which is not permitted at all in other PWR plants before adding boron to the reactor coolant by active systems).
Steam Turbine – Currently Two Options

**GE SPS**
- Arabelle
- HP/IPC + 3 LPC
- Intermediary MSR
- 1500rpm

**Power Machines**
- Turbine K-1200-6,8/50
- 2 LPC + HPC + 2 LPC
- Intermediary MSR
- 3000rpm
ROSATOM: KEEPING THE PACE

ROSATOM SUCCESS STORY:

35 UNITS OVERSEAS NPP PORTFOLIO

12 COUNTRIES

Belarus, Belarus NPP, VVER-1200
Bangladesh, Rooppur NPP, VVER-1200
Turkey, Akkuyu NPP, VVER-1200
India, Kudankulam NPP, VVER-1000

Hungary, Paks II NPP, VVER-1200
Finland, Hanhikivi-1 NPP, VVER-1200
Egypt, El-Dabaa NPP, VVER-1200
China, Tianwan NPP, VVER-1200
HANHIKIVI-1 NPP

Pyhäjoki in Northern Ostrobothnia, FINLAND

Reactor  VVER-1200
Capacity  1 unit x 1200 MW

Highlights
- Rosatom is a partner with 34% stake in the NPP
- Capacity to cover nearly 10% of Finland’s electricity demand

Milestones
- EPC contract signed (December 2013)
- Turbine supplier selected (July 2016)
- Licensing in progress
- I&C systems supplier selected (October 2019)
- Manufacturing of main components started (October 2019)
- Basic Design Stage 1 documentation submitted to customer (December 2020)
- Customer Fennovoima Oy submitted an update to Construction License Application (April 2021)
- Site preparation activities in progress
### PAKS II NPP

#### Paks, Region of Tolna, HUNGARY

<table>
<thead>
<tr>
<th>Reactor</th>
<th>VVER-1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>2 units x 1200 MW*</td>
</tr>
</tbody>
</table>

#### Highlights
- Existing four VVER-440 units at Paks site supplying 40% of Hungary’s electricity
- Strong safety requirements based on EUR and WENRA standards

#### Milestones
- First works on site commenced (2019)
- Basic Design is approved by Hungarian owner (September 2019)
- Set of licensing documentation for a construction license for two new power units is handed over to the Hungarian regulator (June 2020)
- Construction completed of the first two buildings of the construction and erection base (December 2020).

*maximum capacity
## AKKUYU NPP

### Mersin province, TURKEY

<table>
<thead>
<tr>
<th>Reactor</th>
<th>VVER-1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>4 units x 1200 MW</td>
</tr>
</tbody>
</table>

### Highlights
- 1st NPP developed using BOO (Build-Own-Operate) model worldwide
- 1st NPP in Turkey

### Milestones
- Construction licenses granted for Unit 1 (2018), Unit 2 (2019) and Unit 3 (2020)
- Strategic investor status granted (2018)
- Power purchase agreement signed (2018)
- Grid Connection Agreement signed (2019)
- Concreting of Unit 1 foundation (March 2019) and Unit 2 (June 2020) completed
- Core catchers of Unit 1 (October 2019) and Unit 2 (November 2020) installed
- Reactor pressure vessel installed at Unit 1 (May 2021)
# BELARUS NPP

## Ostrovets District, Grodno Region, BELARUS

<table>
<thead>
<tr>
<th>Reactor</th>
<th>VVER-1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>2 units x 1200 MW*</td>
</tr>
</tbody>
</table>

### Highlights
- 1st NPP in Belarus
- Largest Russian-Belarusian project
- Capacity to satisfy nearly 25% of Belarus’ energy demand

### Milestones
- General Contract for construction of Units 1 and 2 (2012)
- Commencement of the stage of cold and hot functional tests of the reactor plant at Unit 2 (March 2021)
- Unit 1 was put into commercial operation (June 2021)

*maximum capacity
**EL-DABAA NPP**

**Matrouh governorate, EGYPT**

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<th>Reactor</th>
<th>VVER-1200</th>
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<tbody>
<tr>
<td>Capacity</td>
<td>4 units x 1200 MW*</td>
</tr>
</tbody>
</table>

**Highlights**
- 1st NPP in Egypt
- Largest Russian-Egyptian project since the construction of the Aswan dam

**Milestones**
- EPC and three lifecycle contracts accrued (2016-2017)
- The contracts came into effect (December 2017)
- Start of preparation works on site (2019)
- Start of construction of Pioneer Base (December 2020)
- Submission of PSAR for Units 1 and 2 to the Owner (March 2021)

*maximum capacity*
## KUDANKULAM NPP

### Kudankulam, Tamil Nadu state, INDIA

<table>
<thead>
<tr>
<th>Reactor</th>
<th>VVER-1000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(2 units in operation, 4 units in implementation)</td>
</tr>
</tbody>
</table>

| Capacity      | 6 units x 1000 MW |

| Highlights    | ▪ High localization level  |
|              | ▪ Southernmost VVER power units in the world |

| Milestones    | ▪ Units 3 & 4 construction started (first concrete in 2017)  |
|              | ▪ Framework agreement for construction of Units 5 & 6 signed (2017) |
|              | ▪ Contracts for the supply of equipment from Russia (2018) and from third countries (2020) |
|              | ▪ Throughout the project, twenty five ship lots with equipment for Units 3 & 4 were sent from Russia to India |
# ROOPPUR NPP

## Pabna district, BANGLADESH

<table>
<thead>
<tr>
<th>Reactor</th>
<th>VVER-1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>2 units x 1200 MW*</td>
</tr>
</tbody>
</table>

### Highlights
- 1st NPP in Bangladesh
- Key energy project in Bangladesh
- Capacity to satisfy nearly 10% of Bangladesh’s energy demand

### Milestones
- Construction of Unit 1 started in 2017, Unit 2 – in 2018
- Installation of reactor support truss of Unit 2 completed (June 2020)
- Reactor pressure vessel and steam generator for Unit 1 delivered to the construction site (November 2020)
- Installation of polar crane in the reactor building 10UJA Unit 1 has began (February 2021)

*maximum capacity*
TIANWAN NPP

Lianyungang city, Jiangsu province, CHINA

Reactor

VVER-1000 (Units 1-4 in operation)
VVER-1200 (Units 7-8 in implementation)

Capacity

2 units x 1060 MW
2 units x 1128 MW
2 units x 1200 MW*

Highlights

Largest Russian-Chinese high-technology project

Milestones

- Units 1 & 2 started commercial operation (2007)
- Units 3 & 4 started commercial operation (2018)
- Detailed Design documentation for concreting the reactor building foundation slab for Units 7 & 8 was developed and submitted to the customer (May 2020)
- License for construction of nuclear island of Units 7 & 8 obtained (May 2021)
- Milestone “Nuclear Island First Concrete Day” of Unit 7 achieved (May 2021)

*maximum capacity
## XUADPU NPP

### Huludao city, Liaoning province, CHINA

<table>
<thead>
<tr>
<th>Reactor</th>
<th>VVER-1200 (Units 3-4 in implementation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>2 units x 1200 MW*</td>
</tr>
<tr>
<td>Highlights</td>
<td>Project for mutual nuclear cooperation extension</td>
</tr>
</tbody>
</table>
| Milestones  | - The general contract for construction of Units 3 & 4 signed (June 2019)  
- Working documentation for the pit was developed and handed over to the customer (February 2020)  
- Preliminary Safety Analysis Report (PSAR) was developed and handed over to the customer (July 2020) |

*maximum capacity
Thank you for your attention

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