Nuclear projects of ROSATOM and Franco-Russian cooperation in nuclear

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Quelles ÉNERGIES pour demain?
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OUTLINE

- Overview of ROSATOM
    - Russian nuclear power development programme
    - International projects of ROSATOM
    - SMRs and fast reactors
- Particular features of VVERs vs. “western” PWRs
- Russia-France Cooperation

OVERVIEW OF ROSATOM

ROSATOM AT A GLANCE

140.0 Bn USD
10-YEAR PORTFOLIO OF OVERSEAS ORDERS

RUSSIAN DESIGNED NPPs AVOIDED
210 M tonnes of CO_2eq

R&D INVESTMENT
4.5% of revenue

250 000
EMPLOYEES

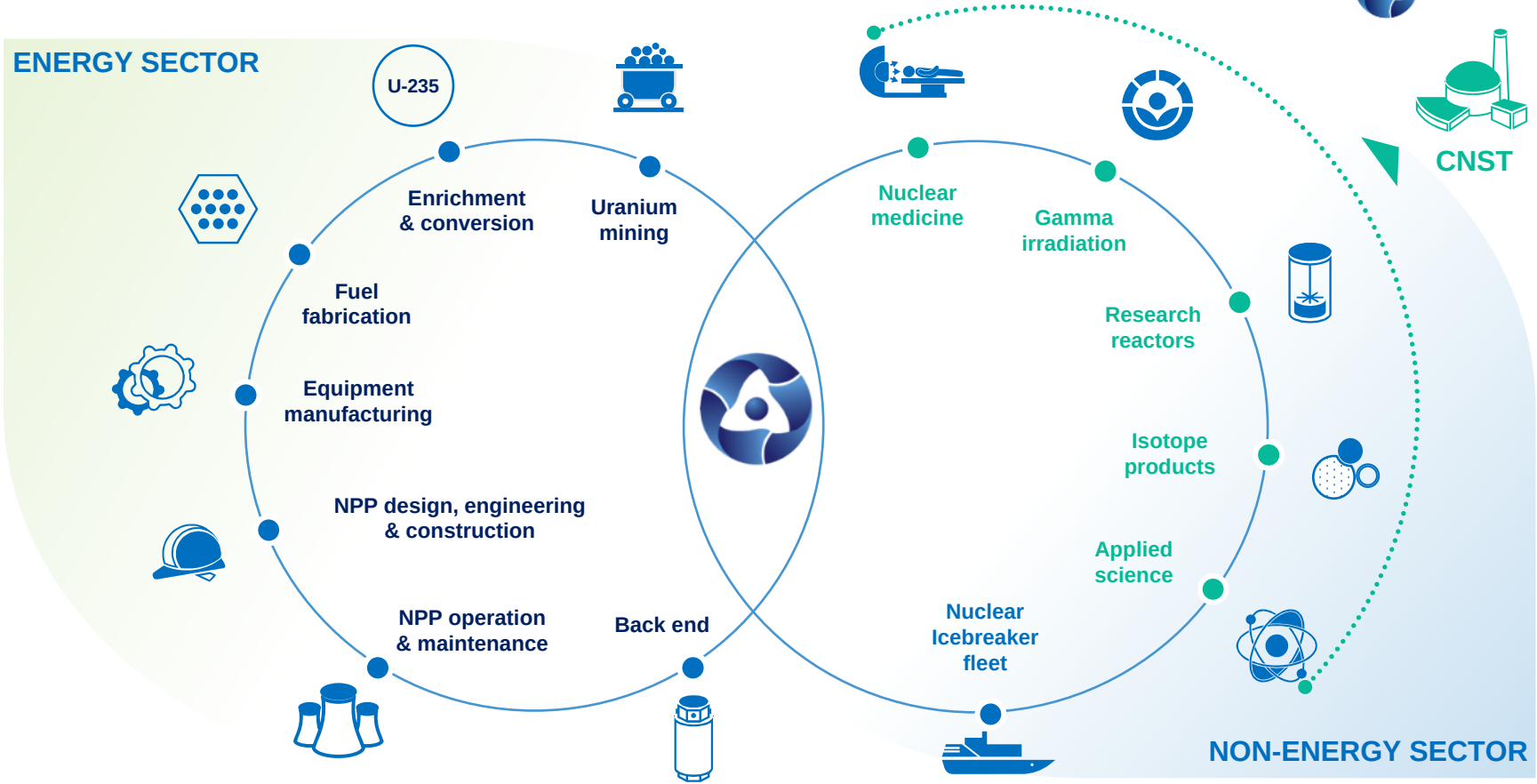
17.8 Bn USD
REVENUE

36 UNITS
IN IMPLEMENTATION ABROAD

0 INES
LEVEL–2 INCIDENTS

GLOBAL FOOTPRINT -
over 50 countries

ROSATOM: ALL THAT IS NUCLEAR



NUCLEAR TECHNOLOGIES CONTRIBUTE TO UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

ROSATOM

- **Nuclear power plants – clean and affordable energy, combat climate change, industry and economic growth**
- **Nuclear Medicine & Isotope products – good health and well-being**
- **Desalination and water treatment – clean water & sanitation**
- **Multipurpose irradiation centers – zero hunger and good health and well being**
- **Centers for Nuclear Science &Technologies – innovation, infrastructure and industry development, good health and well-being and education**

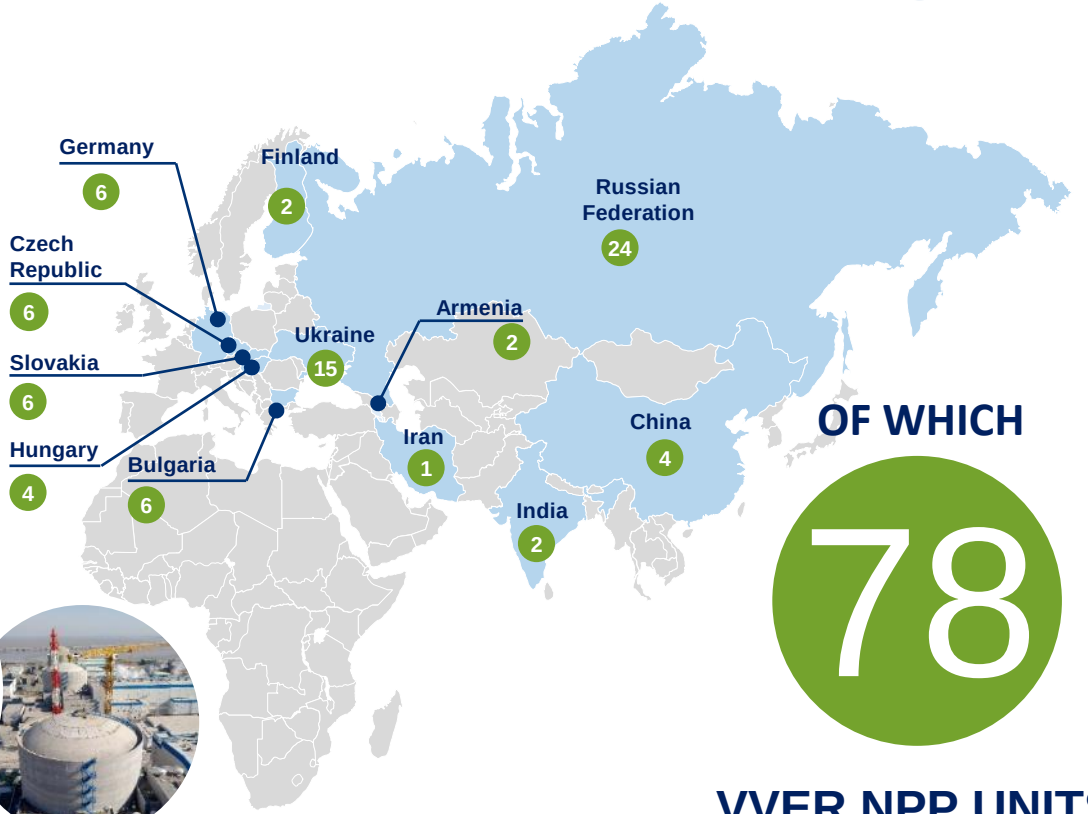
Source: Climate change and nuclear power 2018 IAEA

ROSATOM: ALL THAT IS NUCLEAR

ROSATOM

104

RUSSIAN-DESIGNED NPP UNITS HAVE BEEN BUILT GLOBALLY



OF WHICH

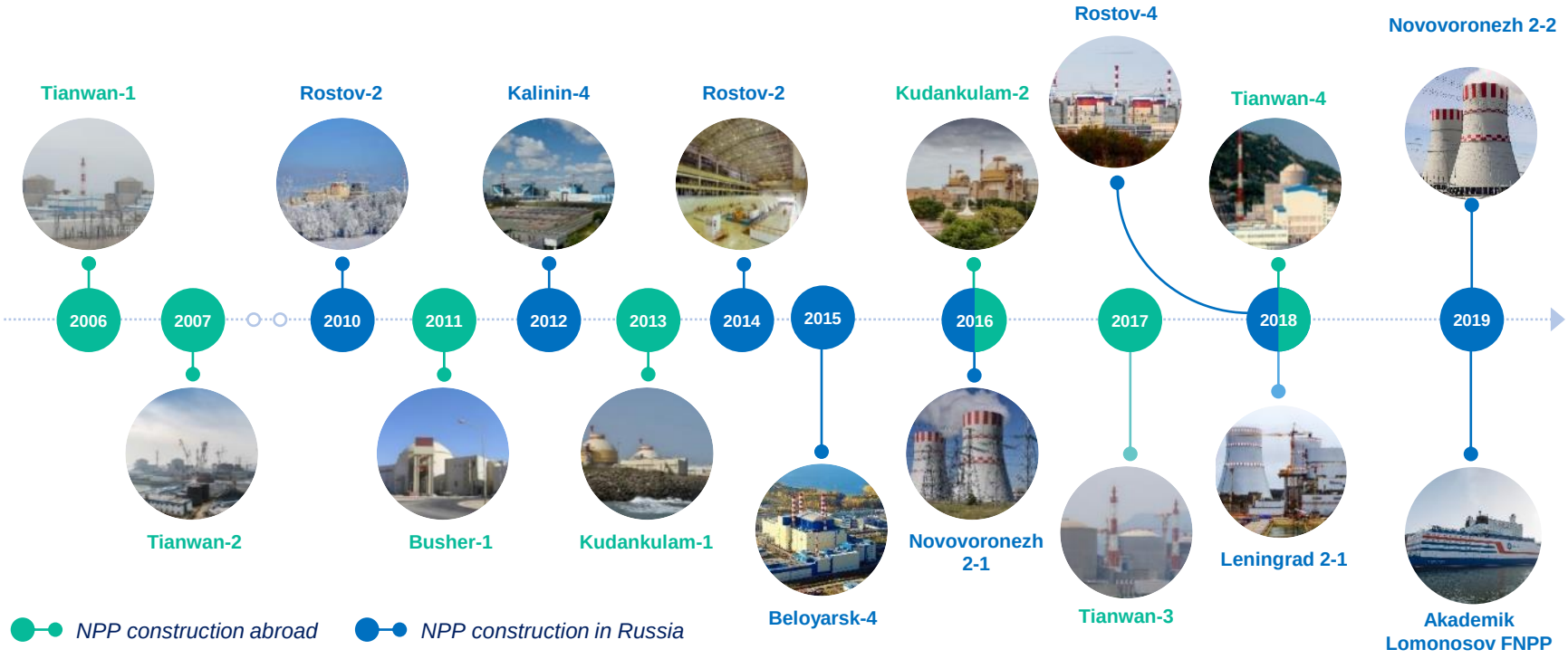
78

VVER NPP UNITS

KEEPING THE PACE: THE ONLY COMPANY IMPLEMENTING SERIAL NPP CONSTRUCTION GLOBALLY

ROSATOM

15 NPP UNITS IN 14 YEARS CONNECTED TO THE GRID



KEEPING THE PACE: NEW PROJECTS UNDERWAY

ROSATOM

PROJECT PORTFOLIO:

36 UNITS	**IN IMPLEMENTATION**
12	**COUNTRIES**

Belarus, Ostrovets 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

RUSSIAN FAST NEUTRON POWER REACTORS

1972
BN-350

1980
BN-600

2016
BN-800

	BN-600	BN-800
Thermal power, MWt	1470	2100
Electric power, MWe	600	885
Design lifetime	30	40
Electricity production in 2020, KWh	10 831 mln	

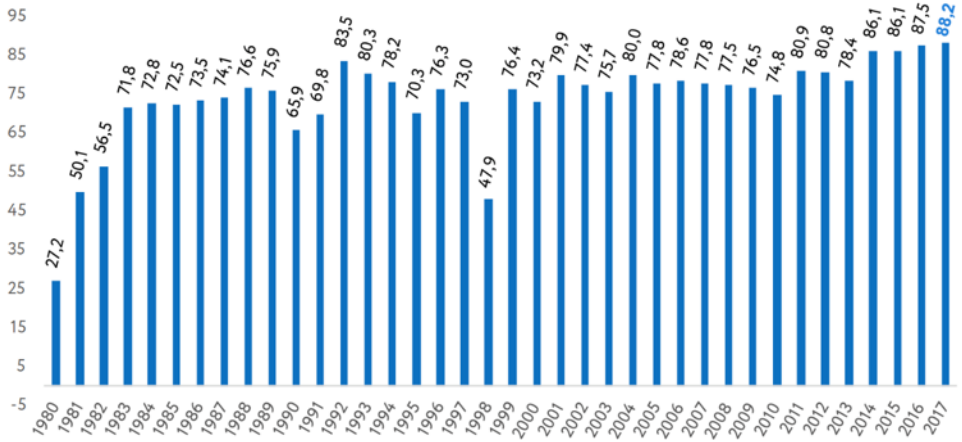
Lifetime-average capacity factor of BN-600: 74.5%

UNIT 3 OF BELOYARSK NPP: BN-600

BN-600 HIGHLIGHTS

- Fuel: UO2
- Start of construction in 1969. Power start-up in 1980
- BN-600 is routinely operated for decades: Lifetime-average capacity factor: 74.5%
- 10 years licence extension granted in 2010, extension for 5 years (until 2025) granted last year. LTO until 2040 is envisaged.

BN-600 Capacity Factor in 1980-2017



MODERN MARKET REQUIREMENTS BRING SPECIFIC DEMAND FOR NEW ENERGY SOLUTIONS

ROSATOM

BASIC NEEDS:

- stable generation
- costs predictability
- low-carbon energy source

NEW REALITY

- EASY GRID CONNECTION
- FLEXIBLE PLACEMENT
- MULTI-PURPOSE APPLICATION
- INTEGRATION WITH RENEWABLES

SMALL MODULAR REACTORS (SMR) SOLUTION TO FIT COUNTRIES NEEDS

ROSATOM WAS THE 1ST IN THE WORLD TO COMMISSION AN SMR

FIRST FLOATING NPP IN THE WORLD

ROSATOM

AKADEMIK LOMONOSOV
FNPP

2 x KLT-40S Reactors

Electrical capacity	Up to 77 MW
Thermal capacity	300 MW
Fuel enrichment	< 20%
Fuel cycle	3 years
Design life	40 years
Mobility	towed

April 2019
Comprehensive testing of the FPU was completed

June 2019
Operation license is issued

December 2019
FNPP is connected to the grid

May 2020
Commercial Operation

6 RITM-200 REACTORS ARE ALREADY MANUFACTURED AND INSTALLED ON ARKTIKA, SIBIR AND URAL ICEBREAKERS

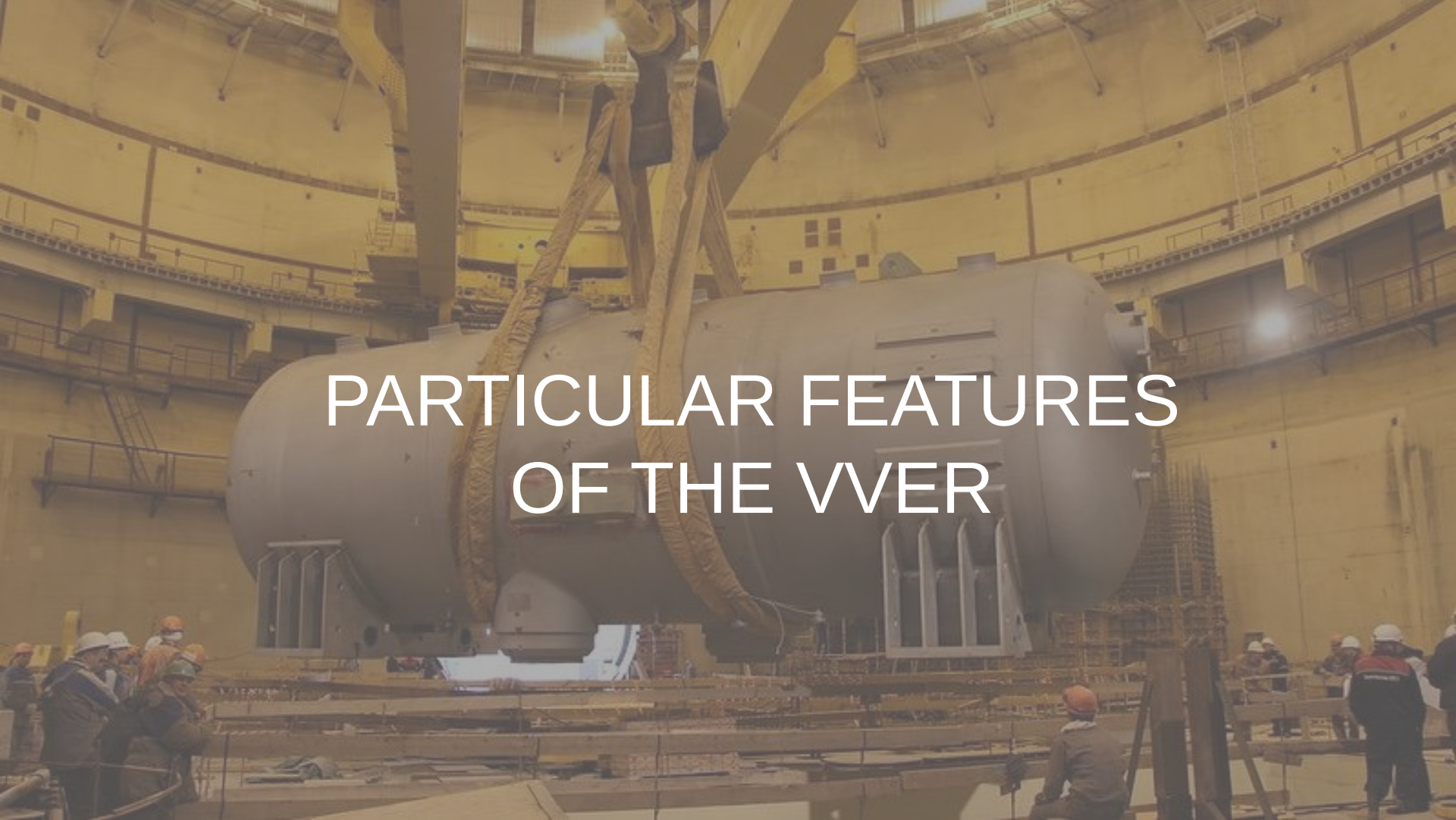
ROSATOM

Two **RITM-200** reactors provide **81 000** shaft horsepower

Variable draught from **8.5** to **10.5** meters

Able to break through ice up to **3** meters

Arktika is at the final stage of sea trials. Sibir and **Ural** to enter operation in **2021** and **2022** respectively



PARTICULAR FEATURES OF THE VVER

PARTICULAR FEATURES OF VVERs VS. ”WESTERN” PWRs

Reactor core:

- Historically, **railroads** were the limiting factor for the RPV diameter → relatively small core → higher enrichment
- Two levels of reactor coolant piping connection to the RPV
- No penetrations in the bottom of the RPV
- Core: **triangular** lattice → **hexagonal** fuel assemblies
- Hydrogen-to-heavy-metal-ratio (H/HM): ~3.8 for VVERs, ~3.5 for PWRs

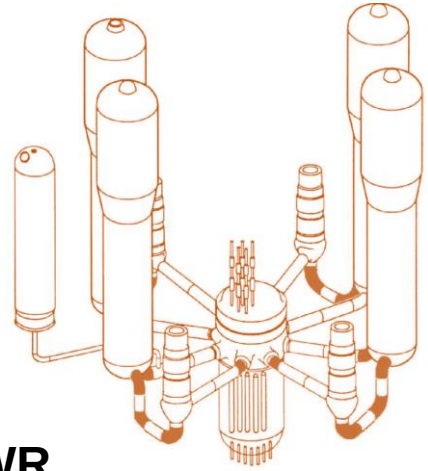
Steam generators:

- Horizontal steam generators → originally larger volume of the reactor building (hence no containment in the first VVERs)
- No need to replace the horizontal steam generators for 60 years

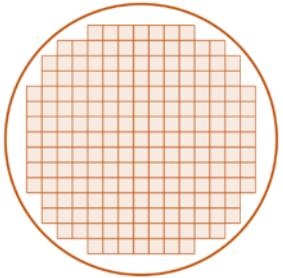
Fuel pool:

- In typical VVER the spent fuel pool is located in the reactor building (capacity of about 390 FA, ~10 years). Separate fuel building is also proposed now

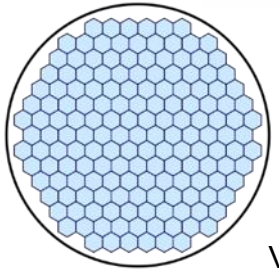
PARTICULAR FEATURES OF VVERs VS. ”WESTERN” PWRs



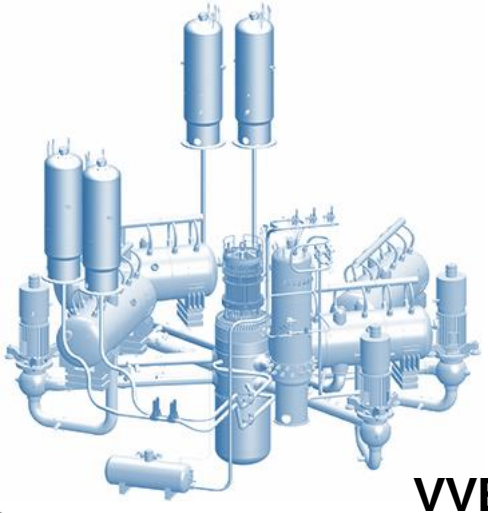
PWR



PWR core
(Westinghouse 4-loop)



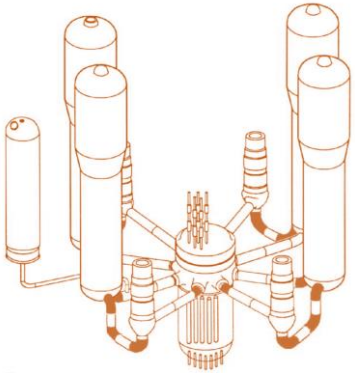
VVER-1000



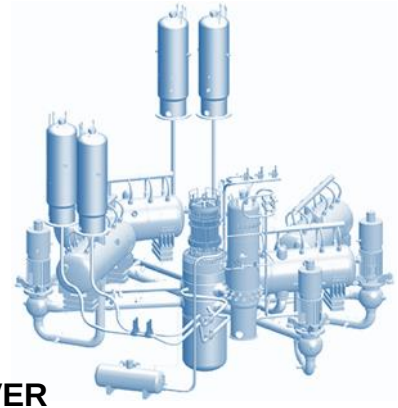
VVER

PARTICULAR FEATURES OF VVERs VS. ”WESTERN” PWRs

Reactor coolant piping is one of the key components of the primary circuit of the nuclear power plant, ensuring circulation of the coolant under pressure and at high temperatures between the RPV, the SG and the MCP



PWR

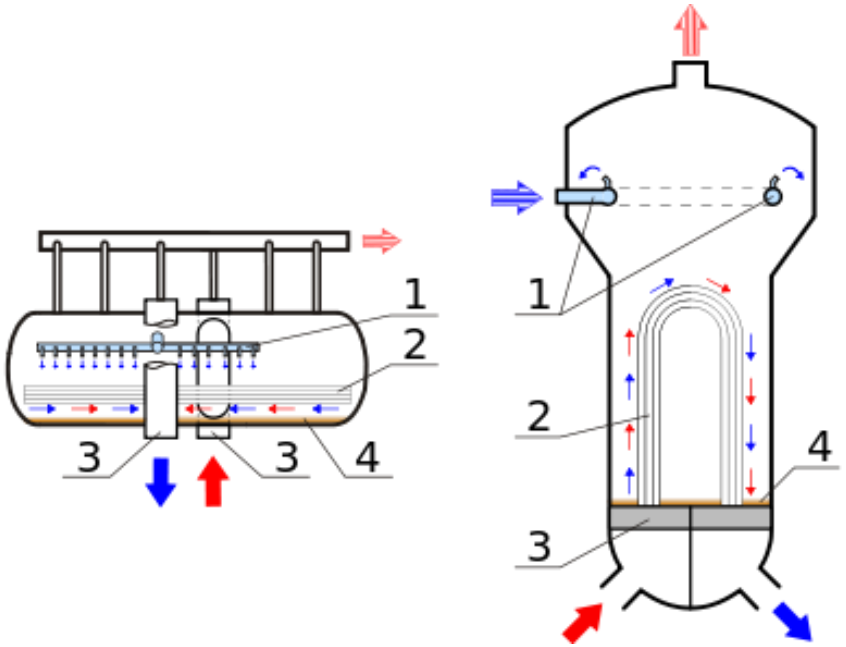


VVER

	REP 900 MWe	VVER 1000 MWe
Internal diameter, mm	787	850
External diameter, mm	931	990
Wall width, mm	72	70
Nominal pressure, bar	155	157
Core outlet temperature, °C	323,2	321
Nominal flow rate per loop, m3/h	21 250	21 500

VVERs STEAM GENERATORS

Horizontal steam generators in VVER type reactors:



1 — Feed water inlet (secondary circuit)

2 — Heat-exchange tubes

3 — Vertical collector (for horizontal SG) and horizontal tubeplate (vertical SG), inlet and outlet of the primary coolant

4 — Most probable places of sludge deposition

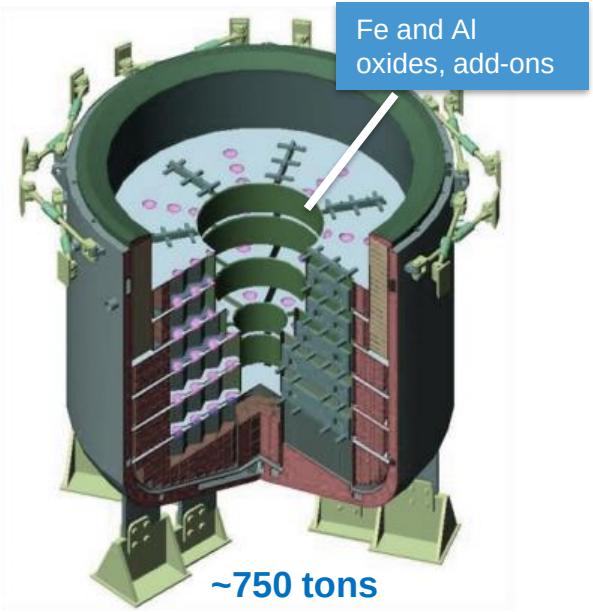
STEAM GENERATOR: HORIZONTAL VS VERTICAL

	VERTICAL STEAM GENERATORS	HORIZONTAL STEAM GENERATORS
ADVANTAGES	+ The thermal efficiency of vertical SG is higher + Vertical disposition allows more compact disposition of equipment and thus smaller containment building	+ Low vibrations + Support on large surface + Seismic stability + Significantly less sediments (sludge) + Easy SG replacement (no need to make a hole in the containment) + Material of the tubes: 08Cr18Ni10T steel (equiv. AISI 321 ou Z8CNT18-10) with ~10% Ni (cost) + Large water inventory + Long service life (no replacement)
CHALLENGES	- Horizontal tubeplate on which sediments (sludge) is accumulated; - Possible vibrations due to high velocity of water in the secondary circuit	- Lower theoretical efficiency - Large containment needed

CORE CATCHERS IN VVERs

- The core catcher is placed below the reactor vessel and protects the containment against the impact of the corium (temperature well above 2000°C)
- It retains the debris and ensures cooldown by (passive) heat transfers to the surrounding water: ensures long-term cooling and solidification of the molten core
- The corium is mixed with a neutron absorbent in order to avoid re-criticality within the core catcher
- Core catcher significantly reduces the H2 generation (typically by a factor 4)
- The crust formed on the surface of the corium reduces considerably the transfer of radionuclides into the containment

✓ **Used in all recent VVER-1000 and VVER-1200 projects**



CONCLUSIONS FOR VVER TECHNOLOGY SECTION

- VVER nuclear power plants have continually improved over the past 50 years and have demonstrated high level of safety and reliability
- NPPs with VVER-1200 reactors have been designed taking into account the latest developments in technology and requirements in terms of safety and security
- The fundamental functions of nuclear safety is ensured by a combination of multiple systems, both active and passive
- VVER designers have already developed, before the Fukushima accident, the safety features of nuclear power plants, commonly suggested for new NPPs after the accident
- Unit No. 1 of Novovoronezh II plant is the first Generation 3+ reactor that has achieved criticality on May 20, 2016.; it was followed by Unit #2 and two units at Leningrad II

WORLD'S FIRST GEN 3+ VVER-1200 REACTORS

NOVOVORONEZH II NPP

Novovoronezh 2-1 entered commercial operation in February 2017

Novovoronezh 2-2 entered commercial operation in October 2019

LENINGRAD II NPP

Leningrad 2-1 entered commercial operation in October 2018

Leningrad 2-2 entered commercial operation in March 2021

RUSSIA-FRANCE COOPERATION

RUSSIA AND FRANCE JOIN EFFORTS TO DEVELOP CLEAN NUCLEAR ENERGY WORLDWIDE

Signing of Strategic Document on Partnership in Peaceful Uses of Nuclear Energy between Russia and France in 2018

- Russia and France has been cooperating in nuclear energy since 1970s
- Up to 1 billion Euro of French content per one Russian VVER NPP unit
- Russia’s Rosatom has in 2019 become a supplier of primary circuit equipment for French NPPs
- This strategic cooperation is highly supported by Presidents of Russia and France

FRENCH CONTENT IN ROSATOM'S GEN 3+ NUCLEAR NEW BUILD PROJECTS (NOT EXHAUSTIVE LIST)

ROSATOM

FREYSSINET

VSL A member of Bouygues Construction

Cabling of containment structure in Rosatom's NPPs

ALSTOM

Supply of ARABELLE™ turbo-generator for Rosatom's NPPs

Schneider Electric

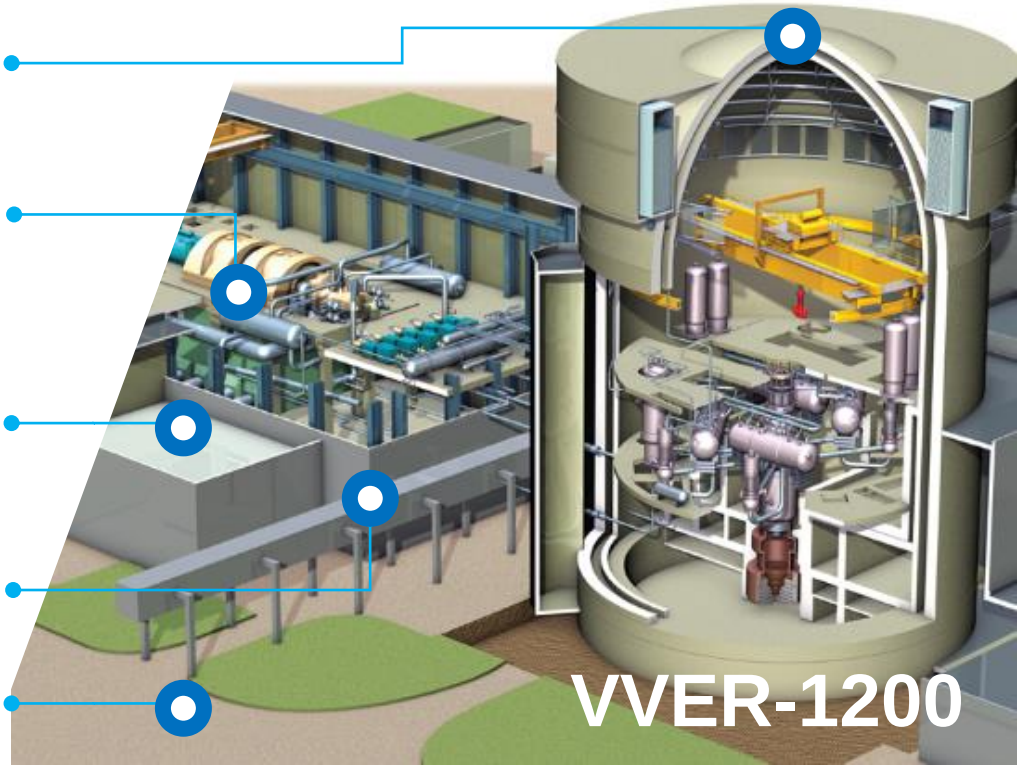
Joint manufacturing of electro-technical equipment

framatome

I&C supply for Rosatom's NPPs projects in Russia and abroad

assystem

Engineering Services



« Aujourd’hui, la filière [française] exporte parce qu’elle parvient à exporter ses savoir-faire sur d’autres designs, en particulier sur les projets VVER en Europe. De l’ingénierie au contrôle commande, Rosatom s’appuie sur la filière française pour son développement à l’étranger. »

« Quand décider d’un renouvellement du parc nucléaire Français ? », Note de Société Française d'Energie Nucléaire, Avril 2019


Thank you for
your attention!