ROSATOM

THE STATE ATOMIC ENERGY CORPORATION ROSATOM

Rosatom Integrated Approach to the Nuclear Energy Development

22 August, 2017

Table of contents

The four main trends will determine the future development of energy

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DEMOGRAPHIC AND SOCIAL CHANGES

- Growth of the population
- Rapid urbanization
- Population ageing

CHANGES IN GLOBAL ECONOMY

- Welfare growth in developing countries

CLIMATE CHANGE AND LACK OF RESOURCES

- Increase in world average temperature
- Emission reductions
- Lack of resources

TECHNOLOGICAL INNOVATIONS

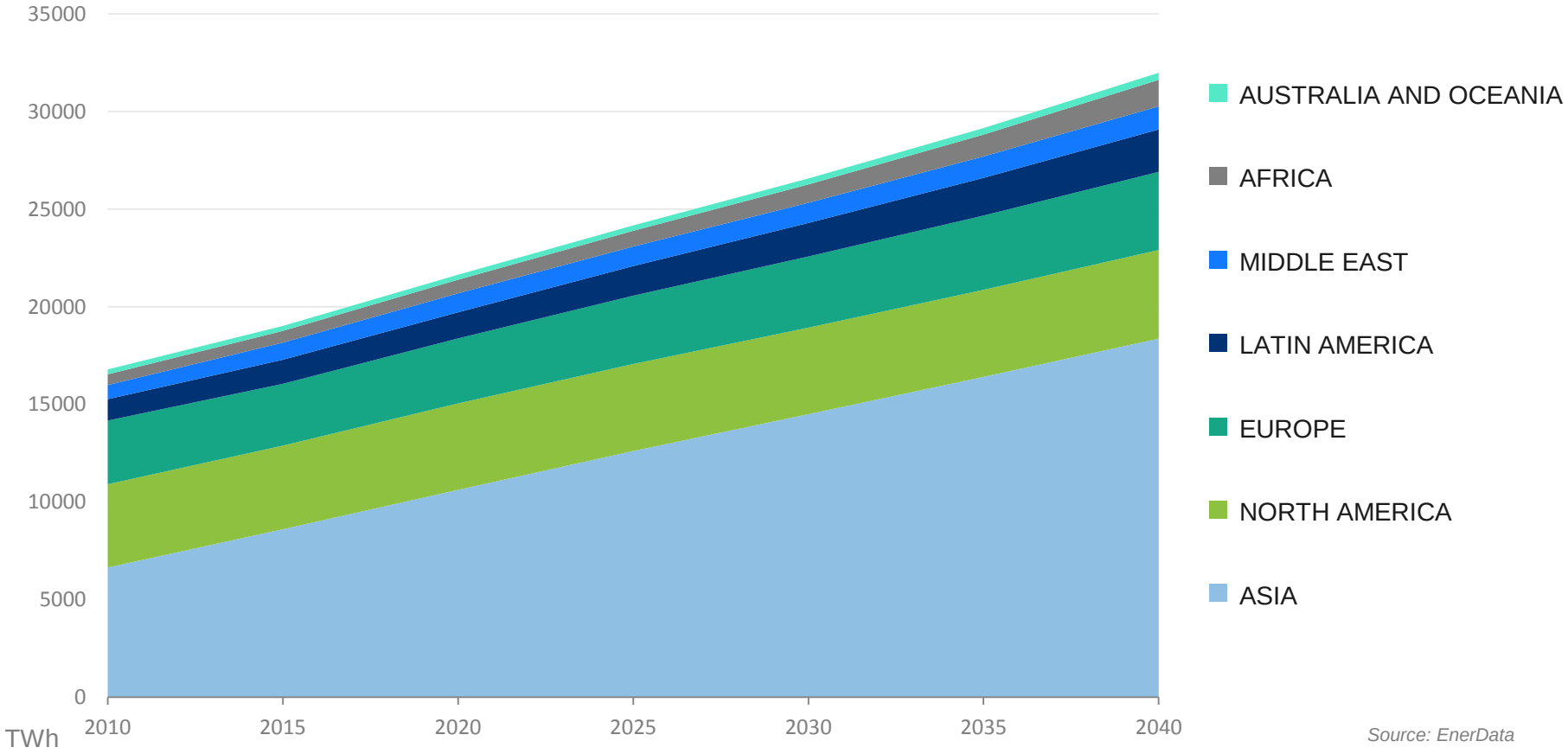
- Cost reduction of the new technologies
- Higher speed of its adoption and implementation

Источник: исследование Strategy&, PWC

Global Electricity Demand-Supply Trends (1/2)

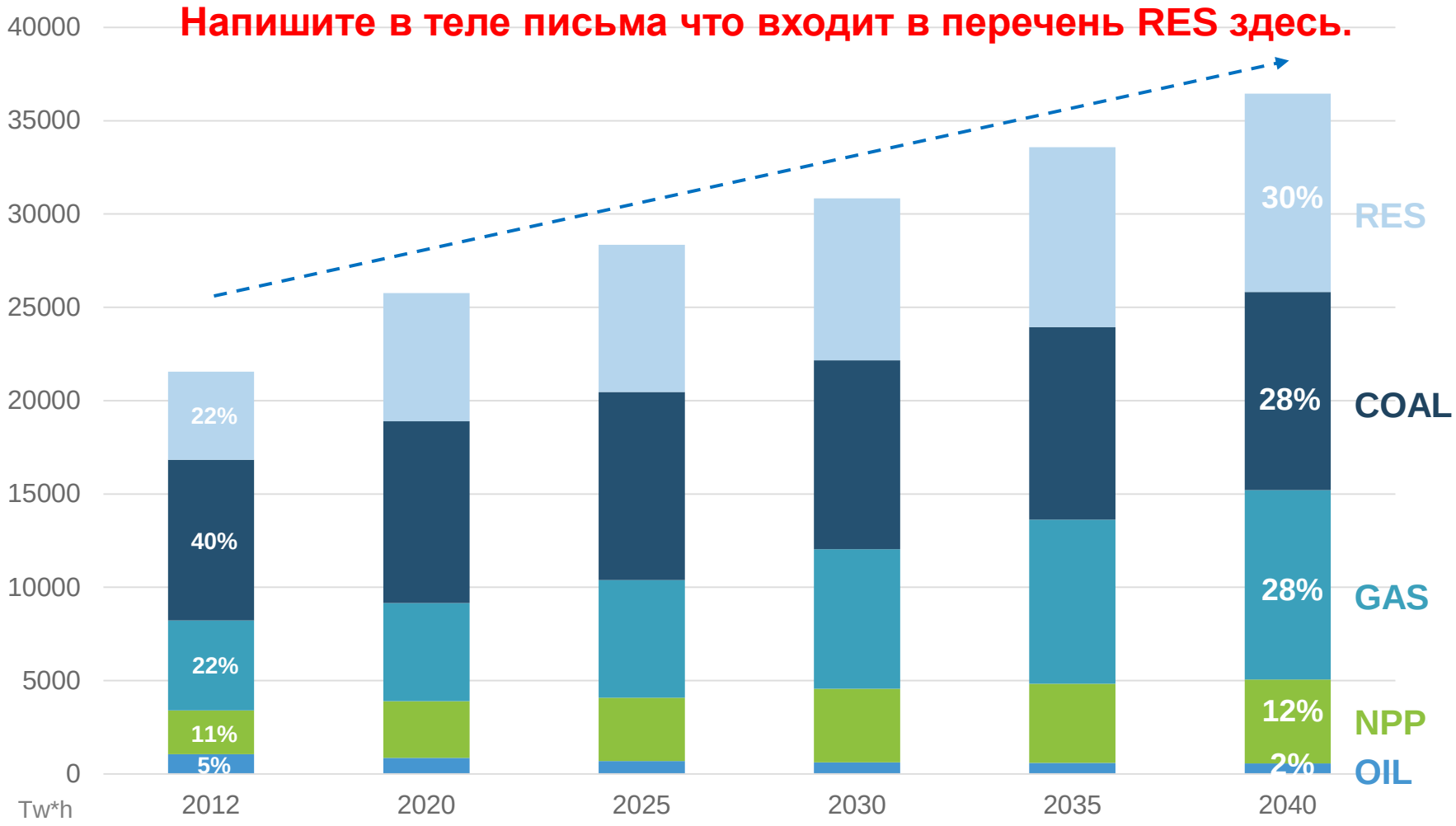
GLOBAL POWER CONSUMPTION WILL EXCEED **30 000** TWh BY 2040

70% GROWTH IN ELECTRICITY DEMAND BY 2040 WITH ASIA INCREASING CONSUMPTION AT THE HIGHEST RATE



Source: EnerData

Global Electricity Demand-Supply Trends (2/2)



Source: EIA, 2016

Global/world energy by 2040

SPECIFIC FEATURES OF THE WORLD ENERGY SECTOR BY 2040 WITH COMPLIANCE OF PARIS AGREEMENT OBLIGATIONS ARE:

37%
Of electricity will be produced by RES (now – 23%)

На 5 слайде RES 30%..

150 mln
Electric cars will be on the roads (today – 1,3 mln)

by 50%
will grow the demand for natural gas (1st place in the energy balance)

by 0,5%
will growth the annual volume of emissions in energy sector

103,5
Mln barrels/day
Volume of oil consumption (in 2015г. – 92,5 mln.barrels/day)

Source – IEA, 2016

Major challenges to Global Energy Sector development. What Are They?

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ENERGY SECTOR IS PREDICTED TO CHANGE BEYOND RECOGNITION IN THE UPCOMING DECADES:

UPCOMING CHANGES
WE CAN'T IGNORE

- Distributed generation
- Smart-grids development
- Surging demand due to electric vehicles sales

IN ORDER TO CREATE A NEW MORE EFFICIENT AND ECO-FRIENDLY ENERGY SECTOR, THE FOLLOWING CHALLENGES SHOULD BE OVERCOME:

CHALLENGES
TO OVERCOME

- Uncurbed CO_2 emissions growth
- Volatile commodity prices
- Rapidly increasing electricity prices

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II. HOW CAN NUCLEAR POWER CONTRIBUTE TO OUR FUTURE?

Nuclear Is…
Sustainable Future

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NUCLEAR POWER SHOULD TAKE AN ADEQUATE SHARE IN GLOBAL ENERGY MIX

CO^2 Emissions by Different Energy Sources

COAL 820 CO_2 kg per MW*h

DIESEL 792 CO_2 kg per MW*h

GAS 490 CO_2 kg per MW*h

NUCLEAR

0 CO_2 kg per MW*h

and only

4 CO_2 kg per MW*h

of indirect emissions during the whole fuel cycle from mining till waste treatment

SOLAR PV 18 CO_2 kg per MW*h of indirect emissions

WIND 7 CO_2 kg per MW*h of indirect emissions

Why Should We Care about CO^2 Emissions?

CO^2 emissions cause climate change which results in:

USD 2000-4000mln

OF DIRECT DAMAGE COSTS PER YEAR BY 2030 ON HEALTH SECTOR, EXCLUDING HEALTH-DETERMINING SECTORS SUCH AS AGRICULTURE, WATER, AND SANITATION.

Nuclear Is…
High Fuel Value

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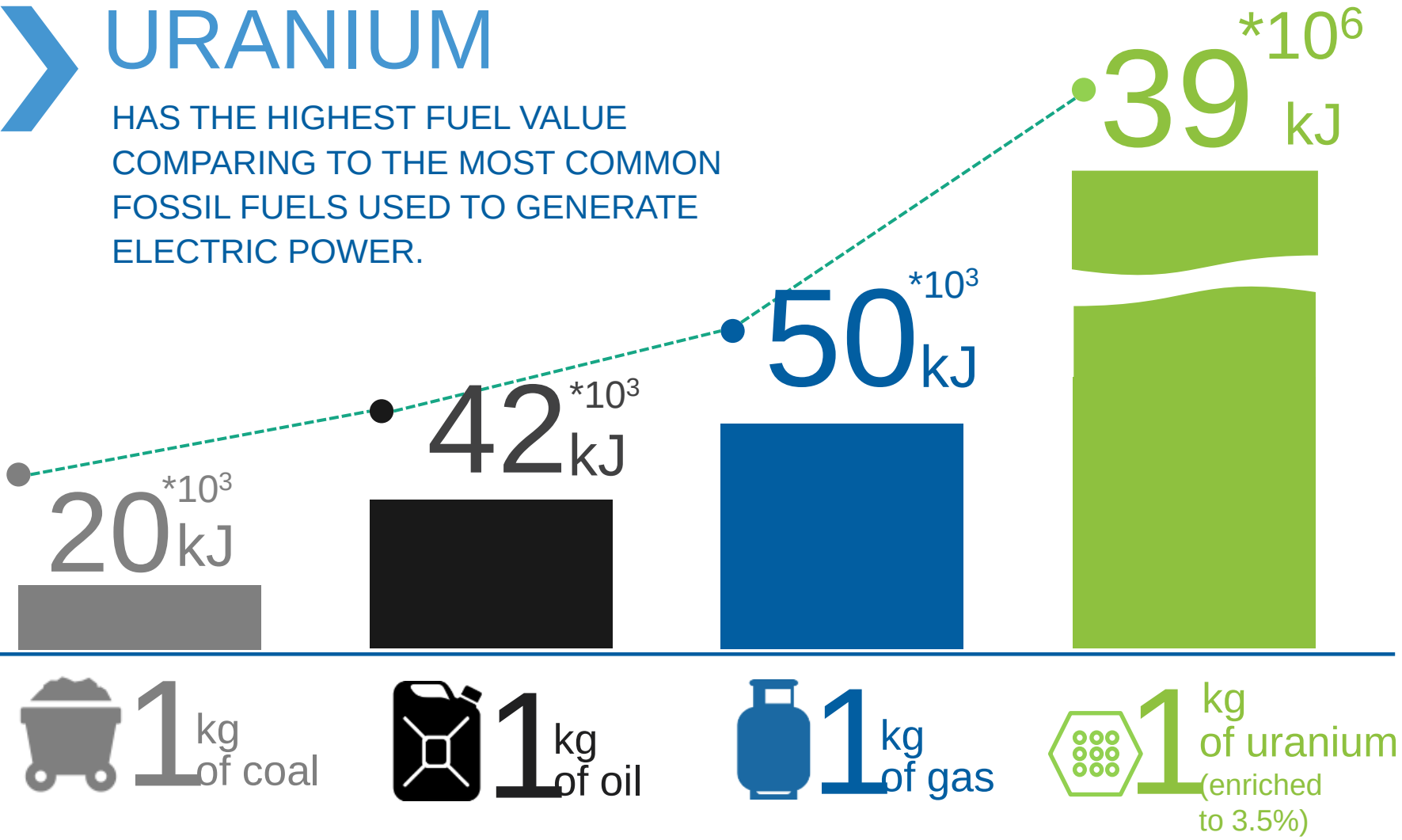
URANIUM

HAS THE HIGHEST FUEL VALUE COMPARING TO THE MOST COMMON FOSSIL FUELS USED TO GENERATE ELECTRIC POWER.



Nuclear Is…
efficient logistics

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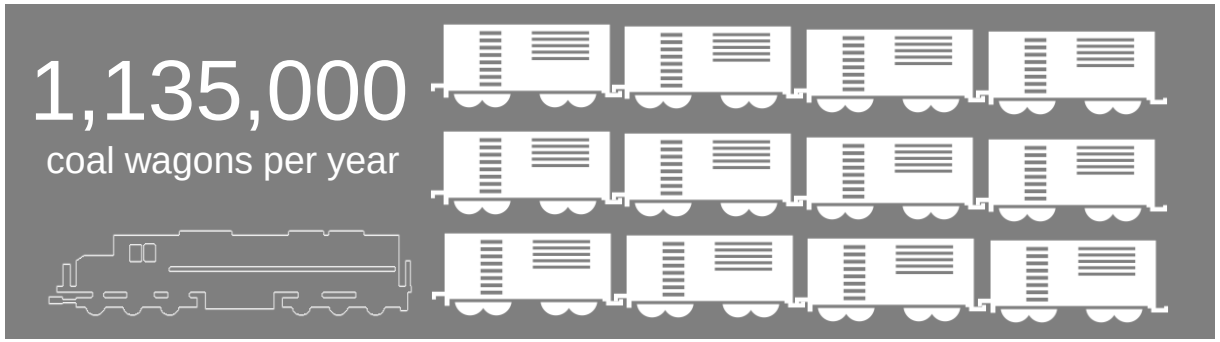
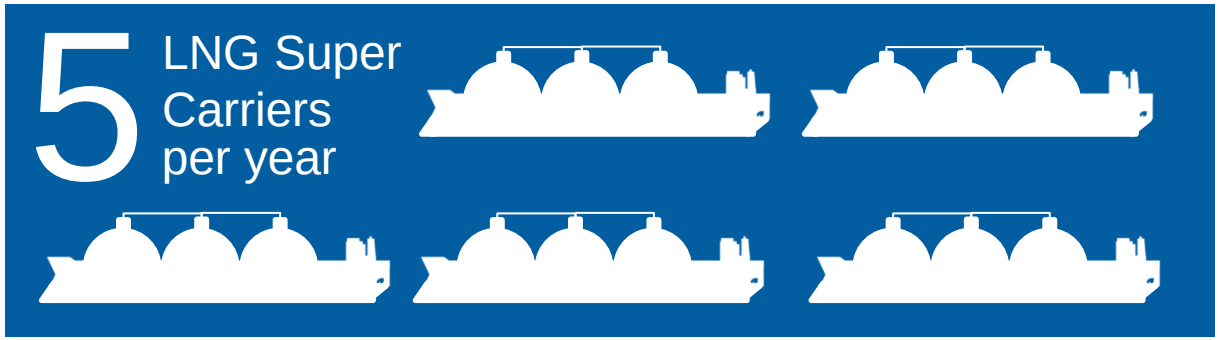
1

VVER 1200

replaces

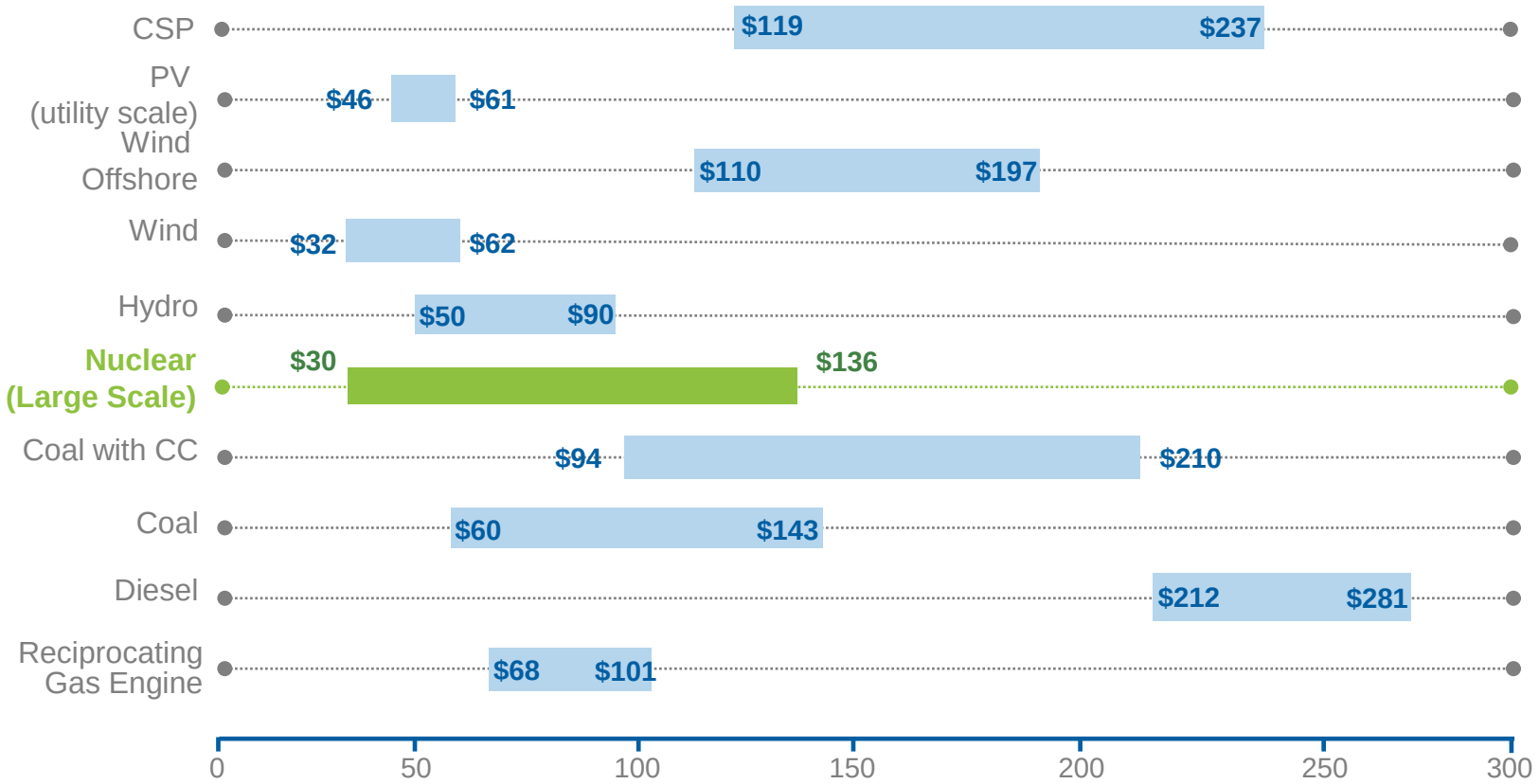




Nuclear Is…
Competitive Cost of Generation

In the recent year global energy landscape has changed dramatically with new renewable technologies emerging and shale gas flooding the market…

… however **NUCLEAR** has maintained its high commercial competitiveness for over 7 decades

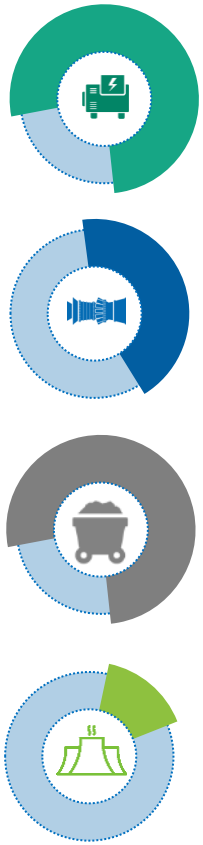


Source: *Lazard's levelized cost of energy analysis – version 10.0 (2016)*
Rosatom internal expertise

Nuclear Is…
Stable Fuel Prices

Most thermal power generating technologies are highly sensitive to fuel prices fluctuations

Share of fuel in LCOE



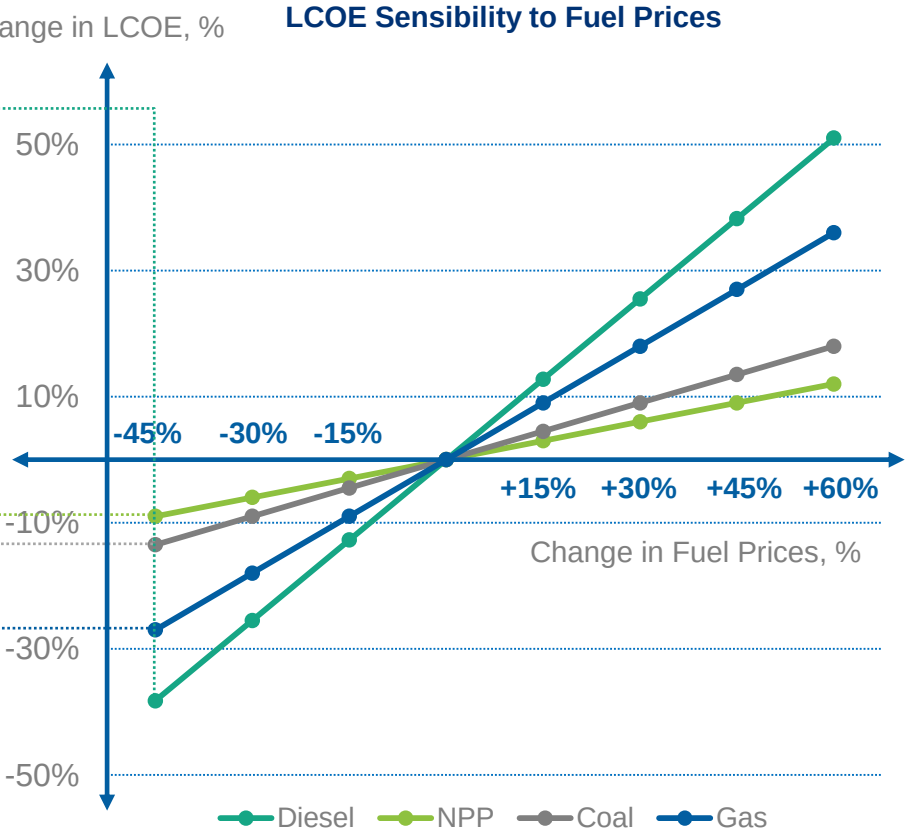
Diesel Generator **85%**

Gas Turbine **60%**

Coal Station **30%**

Nuclear Power Station **20%**

LCOE Sensibility to Fuel Prices



URANIUM PRICES CONTRIBUTE **LESS THAN 10%** TO NPP COST OF POWER GENERATION THAT IS WHY FUEL PRICES HARDLY EFFECT THE COST OF ELECTRICITY PRODUCED BY NUCLEAR POWER PLANTS

Nuclear Is…
Benefits for Local Economies

PUBLIC INCOME

- New taxes from local and foreign suppliers, from electricity sales
- Increasing the region's investment attractiveness

EMPLOYMENT

- Up to 10,000 employed for the development of nuclear infrastructure
- Up to 3,000 new jobs created to operate NPP

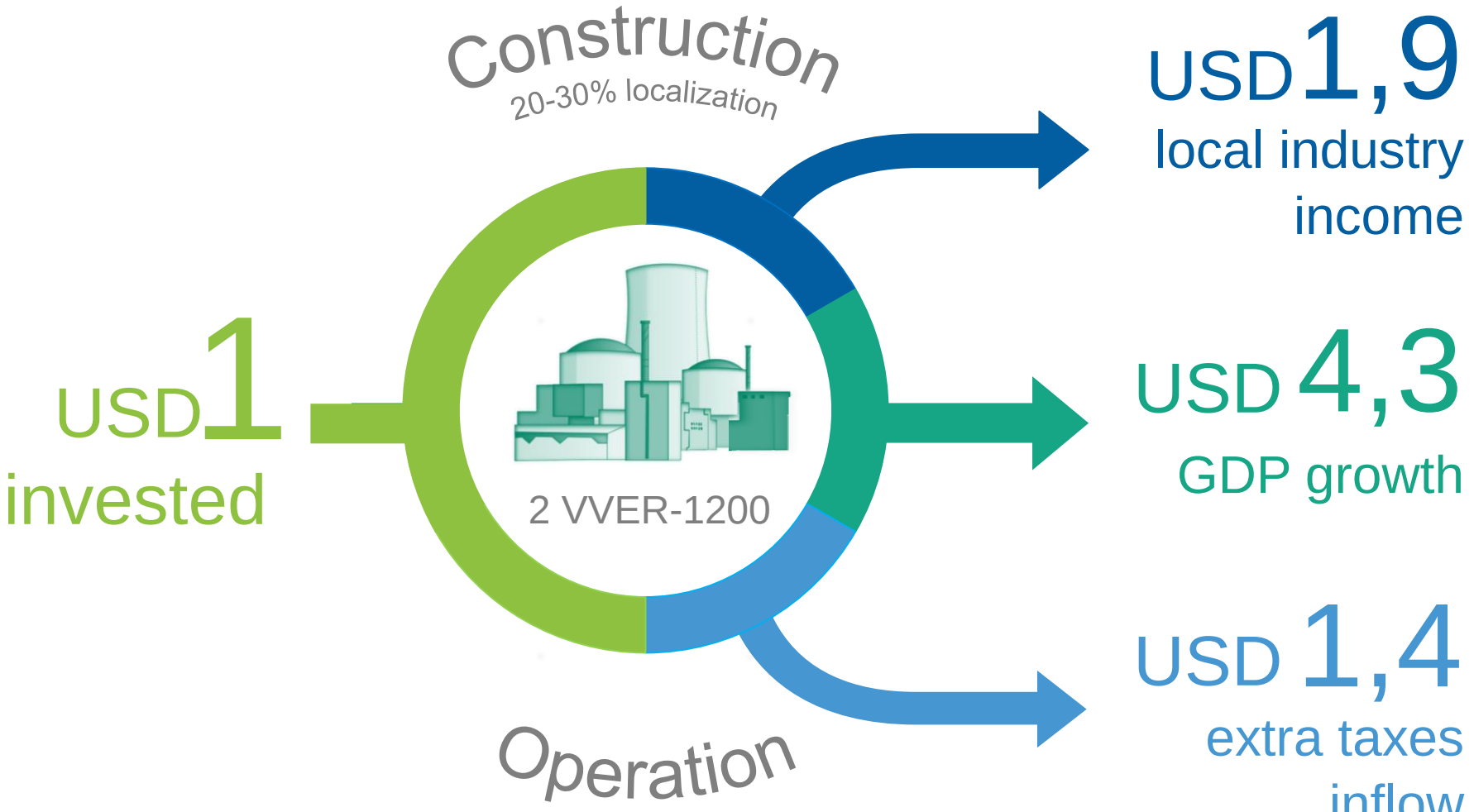
ENERGY SECTOR

- Stable power supply for local industry and household needs
- Reducing electricity prices in the region

NATIONAL DEVELOPMENT

- Developing local higher education and upgrading local labour force skills;
- Facilitating high-tech industries development

Nuclear Is…
Multiplier Effect on National Economy



Nuclear Is…
Jobs Creation

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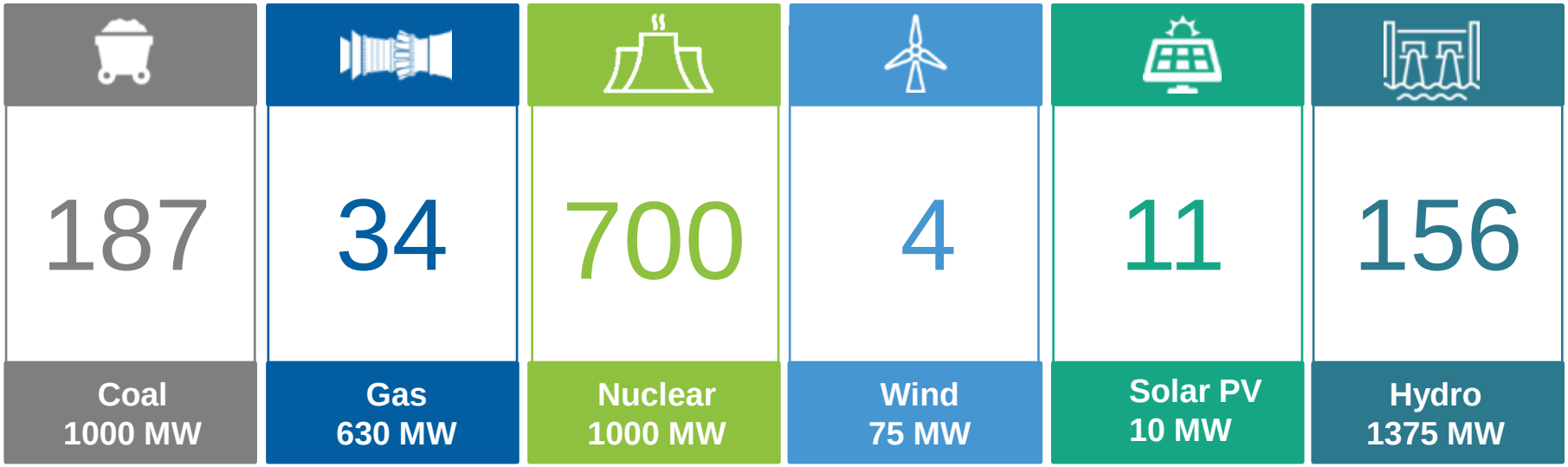
Average Number of Direct Local Jobs Created by Different Technologies



Source: *NEI. Nuclear Energy Economic Benefits and Current Costs.*

NUCLEAR PLANTS CREATE THE LARGEST ECONOMIC BENEFITS COMPARED TO OTHER ELECTRIC GENERATING TECHNOLOGIES DUE TO THEIR SIZE AND NUMBER OF WORKERS REQUIRED TO OPERATE THE PLANT

Nuclear Is…
Dangerous??? Let's Address the Figures… (1/2)

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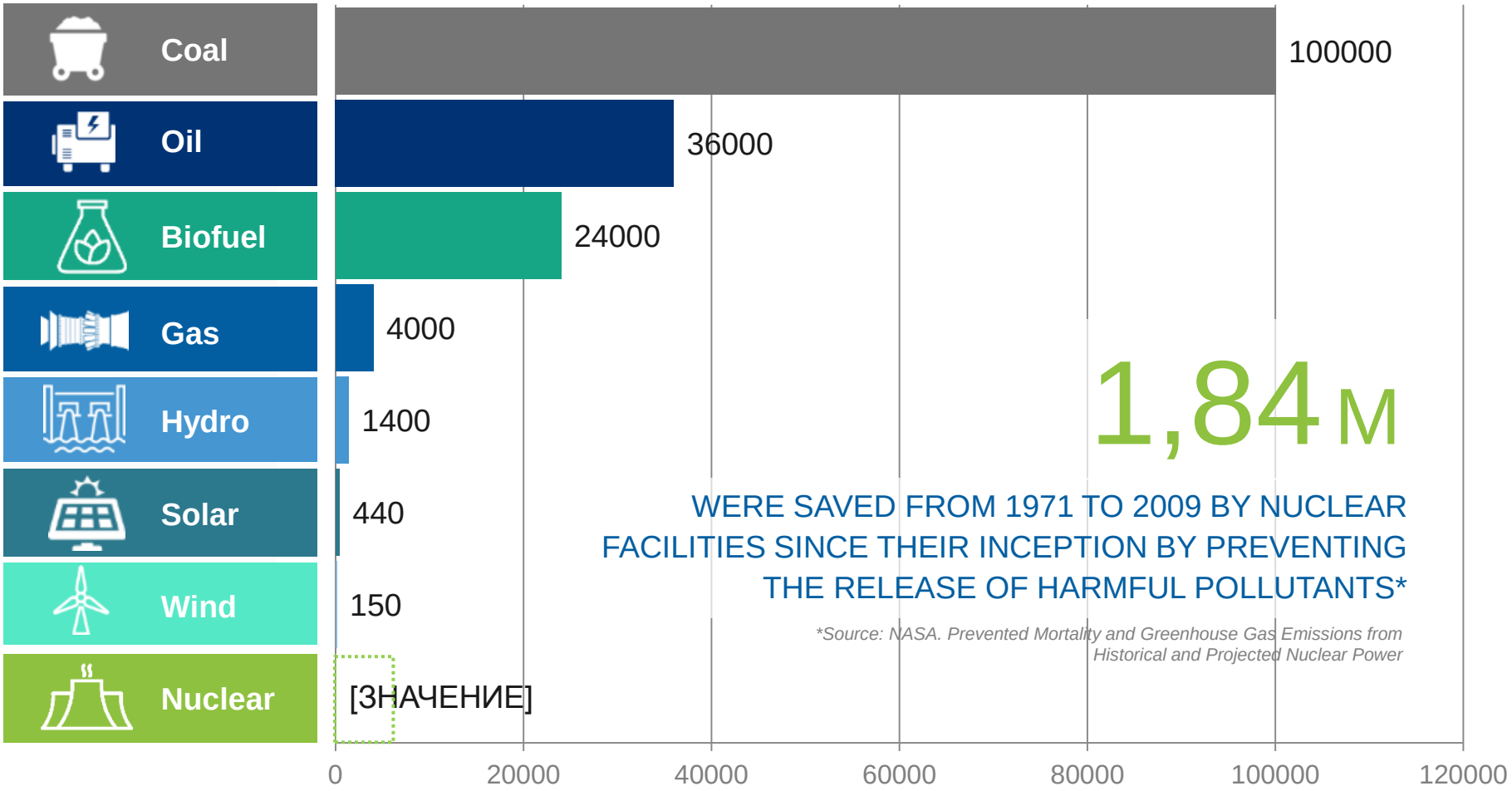
Mortality Rate by Source of Energy (deaths/per trillion kW*h)



1,84 M

WERE SAVED FROM 1971 TO 2009 BY NUCLEAR FACILITIES SINCE THEIR INCEPTION BY PREVENTING THE RELEASE OF HARMFUL POLLUTANTS*

**Source: NASA. Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power*

Nuclear Is…
Dangerous??? Let's Address the Figures… (2/2)

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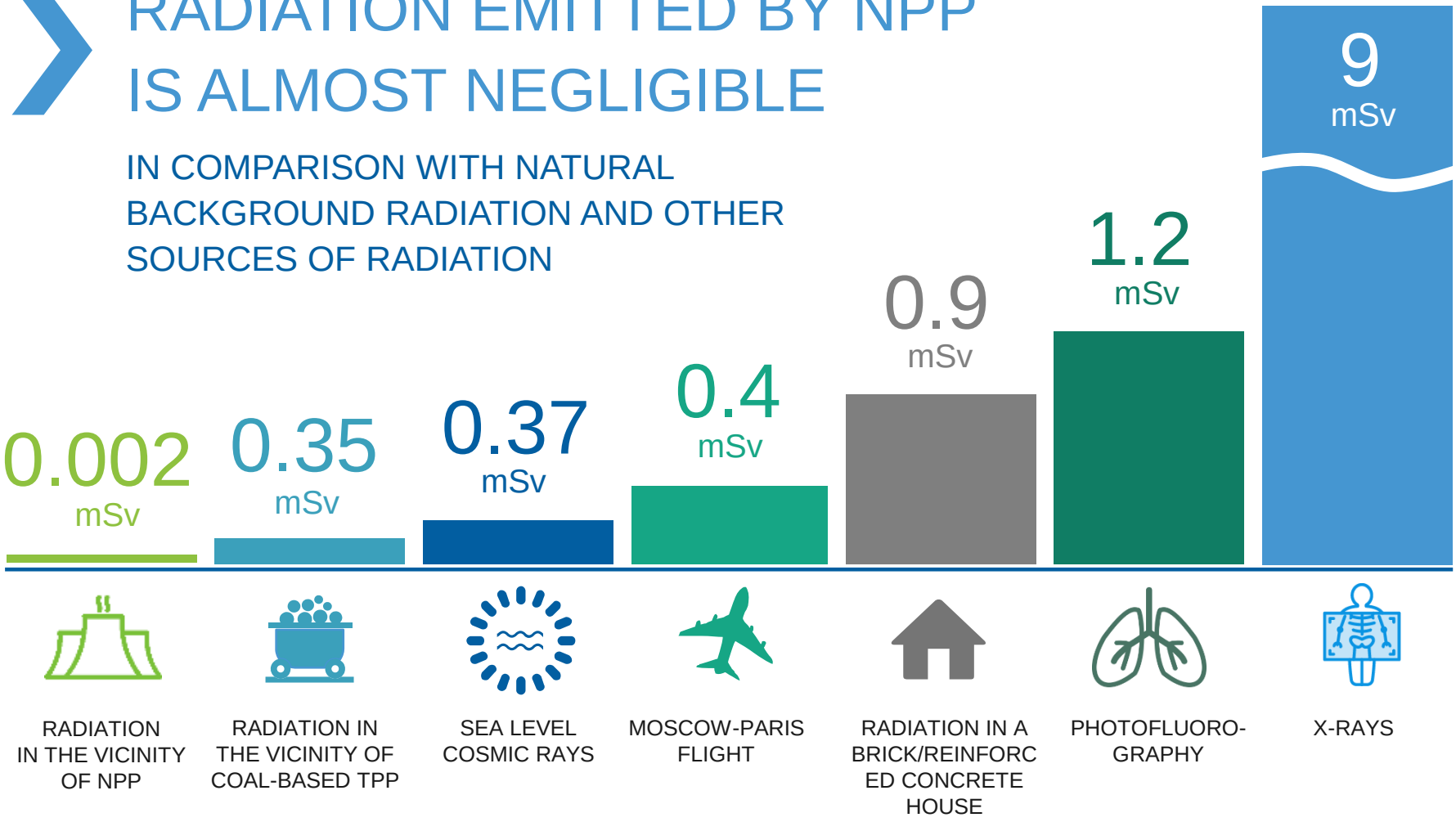
RADIATION EMITTED BY NPP IS ALMOST NEGLIGIBLE

IN COMPARISON WITH NATURAL BACKGROUND RADIATION AND OTHER SOURCES OF RADIATION



Many Countries Have Chosen Nuclear Option

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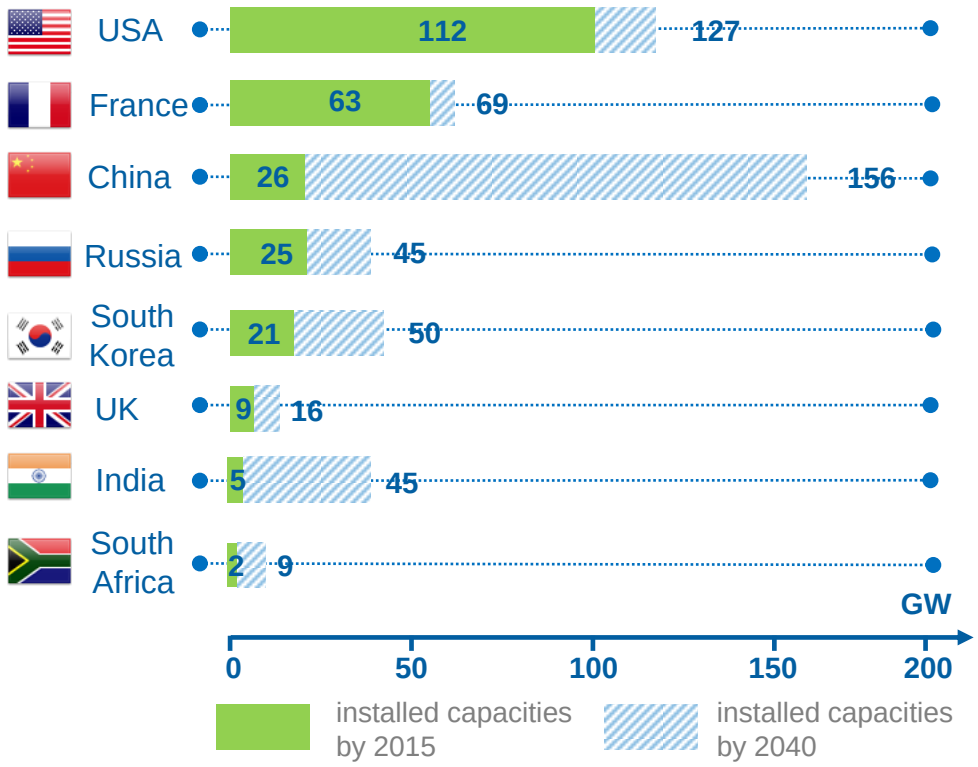
Experienced nations rely on nuclear and plan to expand their installed capacities



Countries in different regions are still willing to harness nuclear energy

1st construction is under way

- UAE
- Bangladesh
- Belarus

Planning to intergrade nuclear into energy mix by 2040

- Egypt
- Turkey
- Jordan
- Saudi Arabia
- Indonesia
- Nigeria
- Ghana
- Philippines

BY 2040 GLOBAL **NUCLEAR** INSTALLED CAPACITIES ARE EXPECTED TO GROW FROM **392** GW UP TO **700** GW

SMR key competitive advantages

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KEY COMPETITIVE ADVANTAGES – OFF-GRID DEPLOYMENT and HIGH MANEUVERABILITY!

Combined with a stable base load output for 60 years and low operation costs **SMRs** are a perfect fit for isolated and remote areas with limited or no access to the power grid.

SIMPLE DESIGN

Simple design is achieved due to extensive use of passive protection systems, which is unavailable for large reactors

POSSIBLE COMMISSIONING WITHIN LIMITED POWER GRIDS

Due to their low output, SMRs can be commissioned within undeveloped or limited power grids

SHORT CONSTRUCTION DURATION

SMR construction duration can be significantly shorter as compared to larger reactors

LOW CARBON GENERATION

SMR contribute to creating a green, low-carbon energy portfolio

STABLE GENERATION

SMRs power output is easy to forecast , which allows to arrange a continuous base-load power supply within a 60-year life cycle.

HIGH MANEUVERABILITY

Can be adapted to changing load conditions

COSTS PREDICTABILITY

Fixed total electricity cost throughout a 60-year life cycle provides for effective cost management

MODULARITY

Additional modules can be attached at any time should the power demand increase.

Modular system and prefabrication allow to reduce erection and construction period costs while increasing overall quality

FLEXIBLE PLACEMENT

SMRs are fit for both, off- and onshore placement

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III. ROSATOM:
MORE THAN ENERGY – REACHING FAR BEYOND

ROSATOM: Energy Major with Global Outreach

27.9 GW

OF INSTALLED CAPACITIES OPERATED **IN RUSSIA**

№1

BY NPP UNITS IN INTERNATIONAL BACKLOG

18,5 %

OF TOTAL RUSSIAN ELECTRICITY GENERATED BY ROSATOM

over 30 %

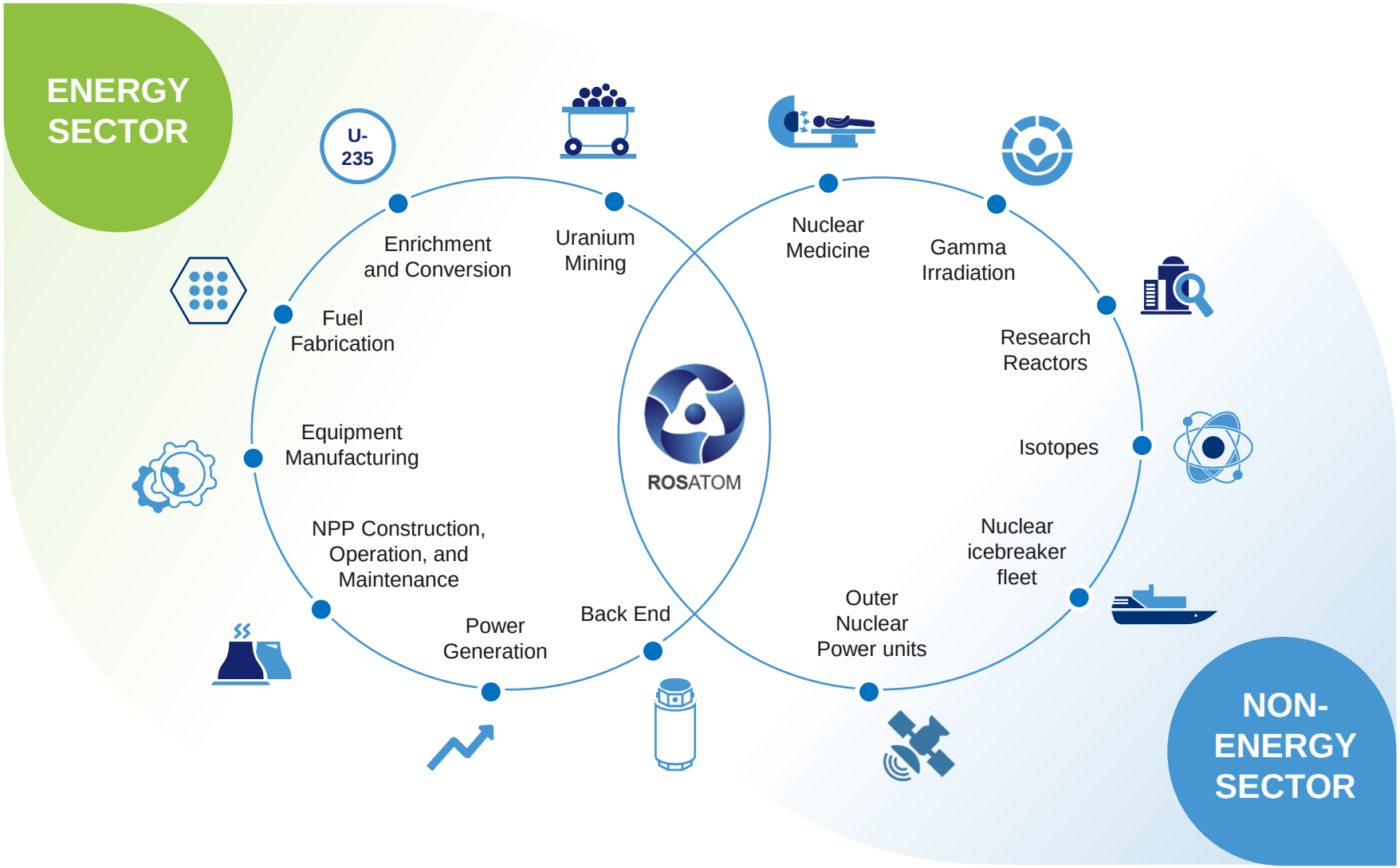
OF GLOBAL **ENRICHMENT MARKET**

U-235

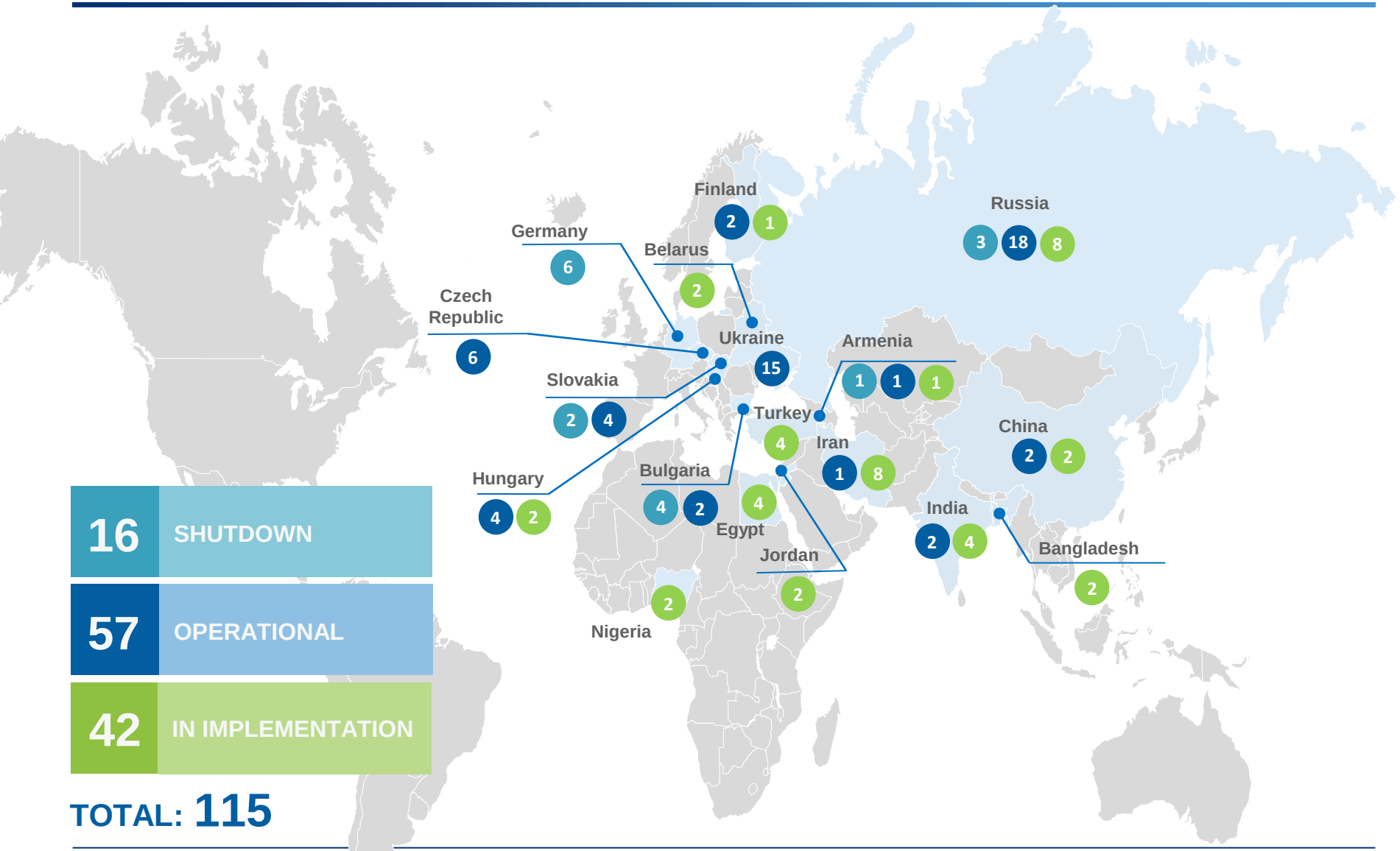
13 %

OF GLOBAL **URANIUM EXTRACTION**

ROSATOM is the world's only company of a complete nuclear power cycle



Rosatom references: Global VVER Fleet



16	SHUTDOWN
57	OPERATIONAL
42	IN IMPLEMENTATION

TOTAL: 115

Rosatom Intergrated Approach

Planning to Implement First NPP Project: What to Start With?

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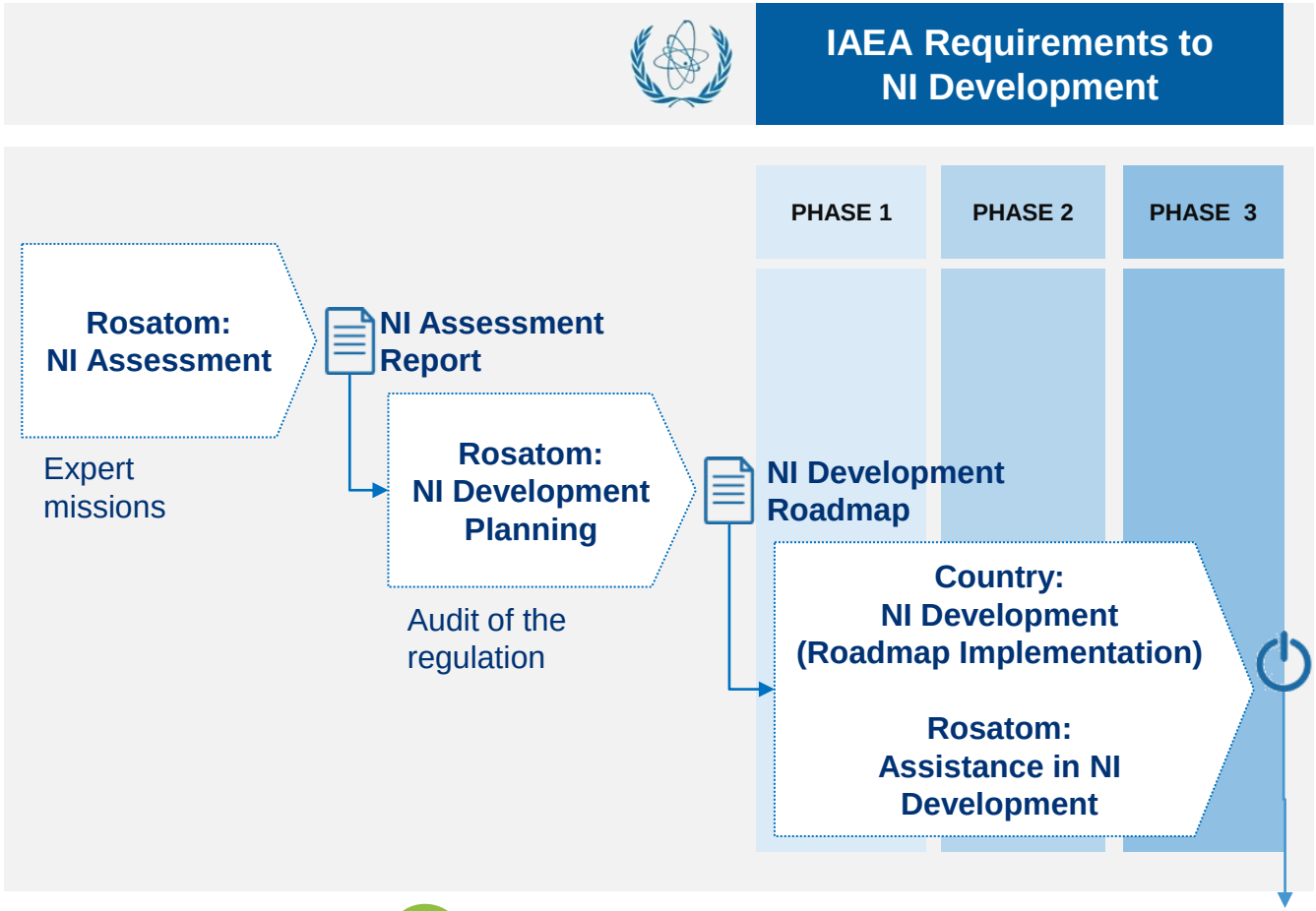
ROSATOM ASSISTANCE IN NUCLEAR INFRASTRUCTURE (NI) DEVELOPMENT



ROSATOM OFFERS
expertise in Nuclear Infrastructure

19
ISSUES
recommended by IAEA

2
EXTRA ISSUES
based on Rosatom projects experience

REFERENCE
to the NPP / RR Project schedule

PROJECT RISKS MITIGATION

COUNTRY IS READY FOR THE NPP / RR OPERATION

How ROSATOM Helps its Partners in Raising the Level of Public Acceptance?

ROSATOM ASSISTS ITS PARTNERS IN RAISING DOMESTIC LEVEL OF PUBLIC ACCEPTANCE AT THREE MAJOR STAGES :

1. Conducting survey on public acceptance of nuclear energy
2. Developing communication programmes for all groups of stakeholders
3. Implementing communication programmes

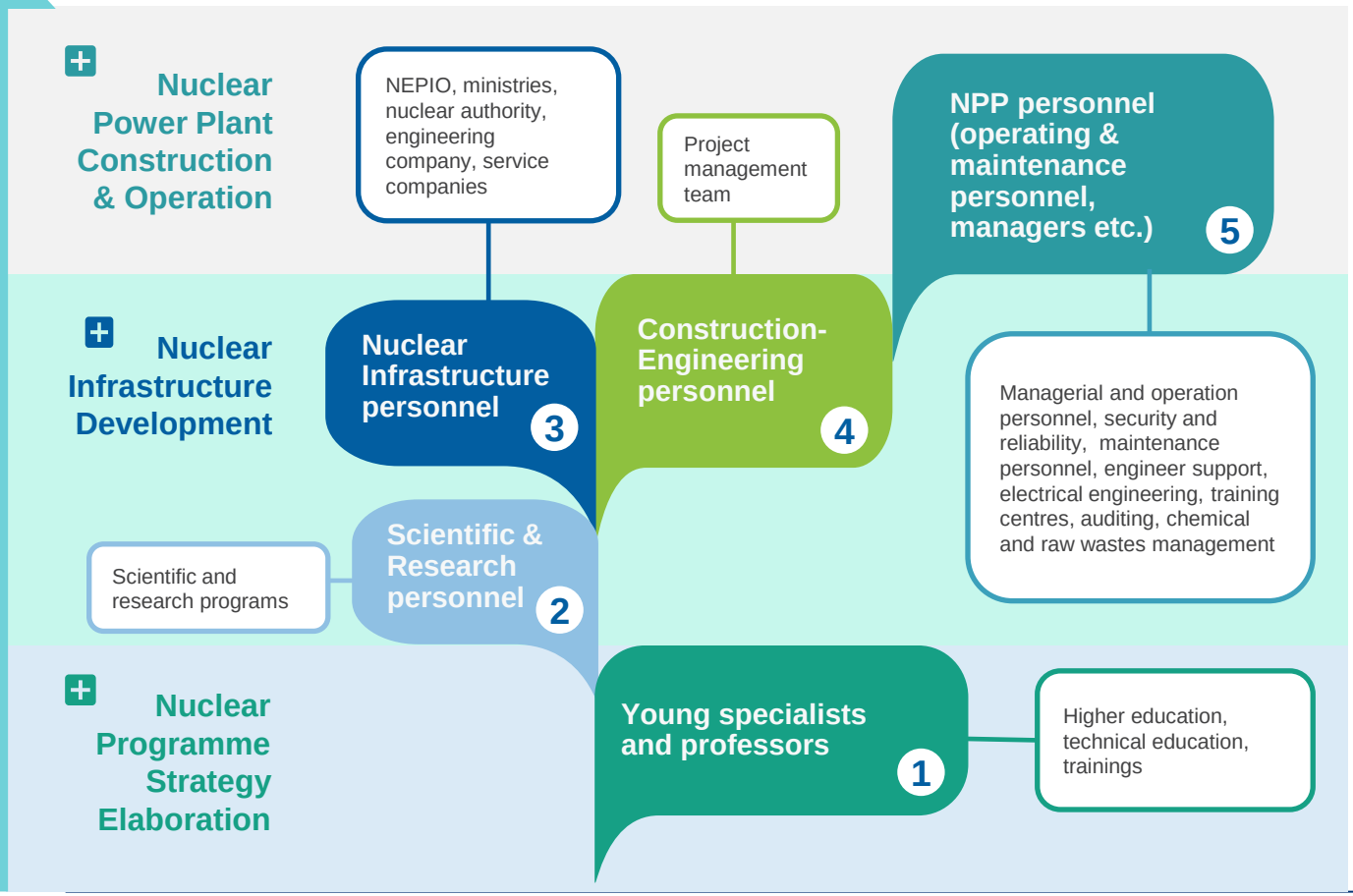
COMMUNICATION PROGRAMME ELEMENTS:

Rosatom Human Resources Development Solution

STAGES OF A NUCLEAR PROJECT LIFECYCLE

ROSATOM HUMAN DEVELOPMENT RESOURCES SOLUTION

Complex solution to prepare **5 CATEGORIES** of nuclear facility project **PERSONNEL**



TYPE OF EDUCATION

- Continuing professional education (CPE)
- Higher education (HE)

TYPE OF TRAINING INSTITUTION

- Institution of higher education
- Industrial-scale training institution

TRAINING FORMAT

- Full-time attendance
- Combined (distant and pat-time) attendance
- On-line attendance

Rosatom Staged Approach to Local Industry Involvement

LEVEL OF LOCALIZATION DEPENDS ON THE PARTNER TECHNICAL QUALIFICATION, FINANCING MODEL, PERFORMANCE OF LOCAL SUPPLIERS, AND APPLICABLE CERTIFICATIONS.

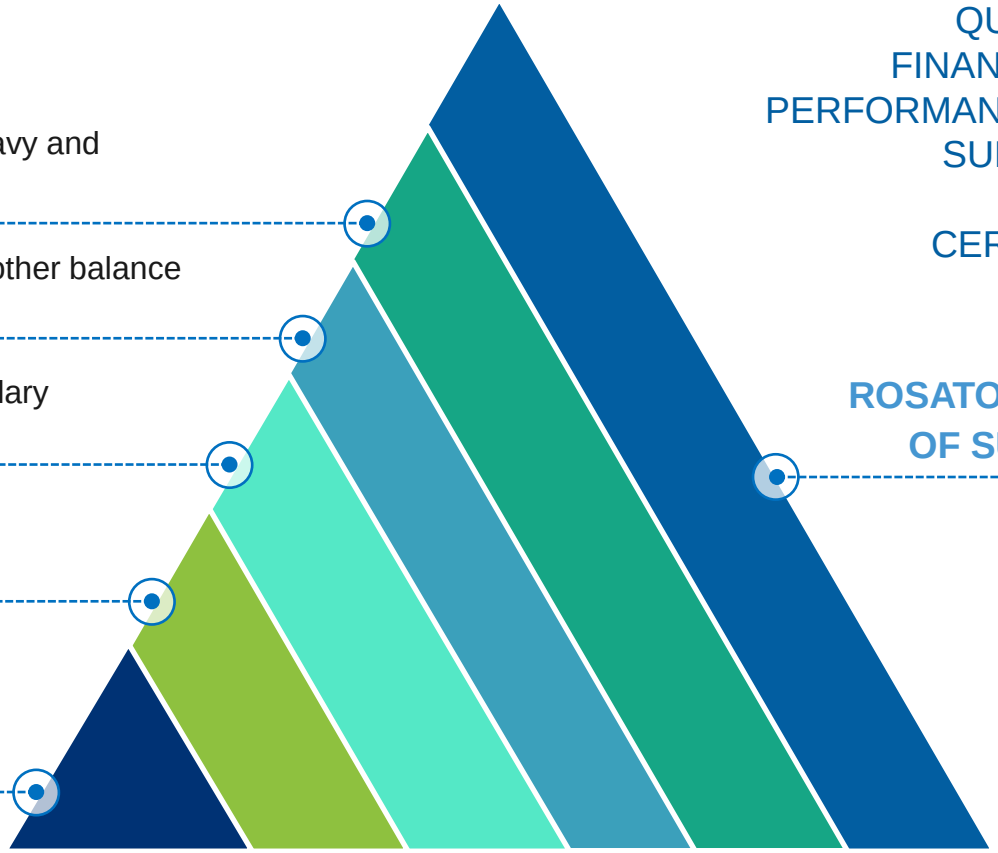
Local manufacturing of heavy and specialized equipment

Engineering services and other balance of plant equipment

Non-critical parts and ancillary equipment

Full or partial responsibility for the civil works and ere

Local labor, construction materials, consumables, tools and materials at site, site infrastructure



ROSATOM SCOPE OF SUPPLY

EXPANSION OF LOCAL INDUSTRY INVOLVEMENT

Advanced Technology: Rosatom Gen III+ VVER Design

VVER-1200 – FUSION OF TECHNOLOGICAL HERITAGE AND INNOVATIONS

First-of-a-class PWR Technology

Performance Indicators

Nominal Output	1,200 MWe
Life cycle	60+
Efficiency	37%
Own power consumption	≈ 7.5%
Availability	> 0.9
Maneuverability	base load
Turbine	low Speed/high Speed
Maximum Fuel burn-up	up to 72 MW*day/kg
Safety systems	active + passive
Seismic load	depends on the site

First VVER-1200 Project Implemented Novovoronezh NPP-2

MORE TO GO:

- **Leningrad NPP (Russia)**
- **Paks NPP (Hungary)**
- **Hanhikivi NPP (Finland)**
- **Belorussian NPP (Belarus)**

- **NOVOVORONEZH-6** CAN BE CALLED THE **FIRST** AND **ONLY GENERATION III+** NPP IN THE WORLD THAT IS ALREADY PRODUCING POWER.
- **VVER-1200** REACTOR TECHNOLOGY IS EMPLOYED AT THE UNIT – A FIRST-OF-A-CLASS PWR TECHNOLOGY, COMPLIANT WITH POST-FUKUSHIMA SAFETY REQUIRMENTS.

Rosatom Complex Fuel Supply Solution

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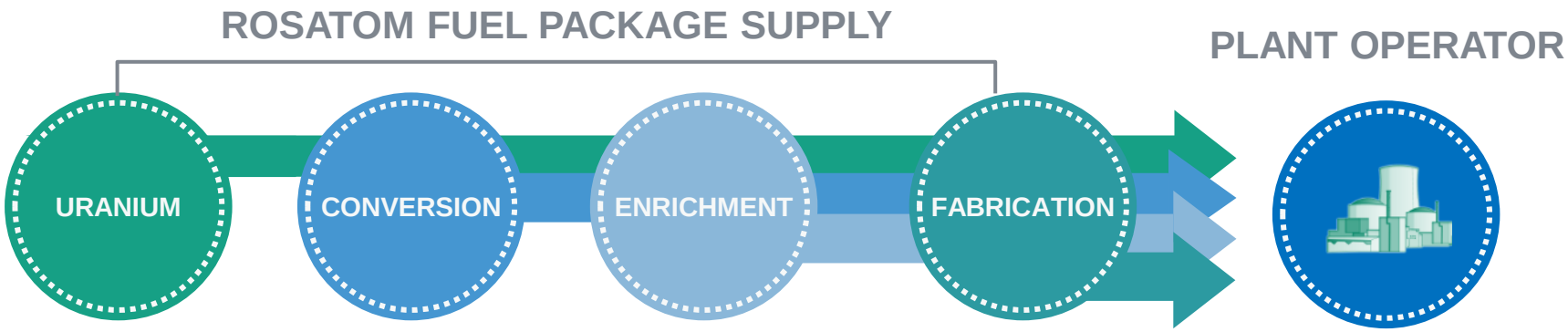
Every 6th power reactor in the world runs on ROSATOM nuclear fuel

ROSATOM provides nuclear fuel for

78 power reactor units in 15 countries

Research reactors in 9 countries



- 2nd largest uranium reserves in the world.
- Fuel fabrication facilities are flexible in terms of production load
- Nuclear fuel shipment via a variety means of transport.

- No risk for Plant operator in finding and purchasing products and services of NFC Front End
- No extra expenses for additional operations
- No extra cost for logistics

NPP Operation & Maintenance

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NPP OPERATION MANAGEMENT

Technical assistance during NPP commissioning, operation, and also arrangement and performance of preventive maintenance

NPP MAINTENANCE DOCUMENTS MANAGEMENT

Maintenance and Repair documents development

NPP MAINTENANCE MANAGEMENT

Maintenance and repair of mechanical equipment, electrical equipment, I&C hardware, and metal examination during NPP operation

NPP EQUIPMENT LIFE MANAGEMENT

Equipment and spare parts supply during NPP commercial operation

Comprehensive NFC Back-End Solution

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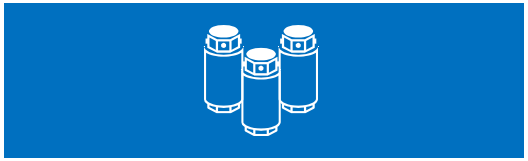
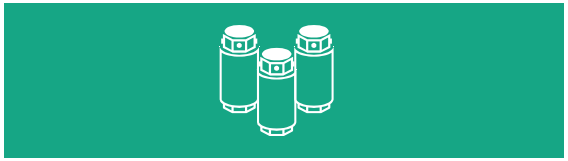


SNF Management

- SNF interim storage in dual-purpose casks of Russian design
- SNF transportation (by railway or sea) to Russia for further reprocessing
- SNF long-term storage



RW Management

- Treatment and conditioning of RW generated during NPP operation
- Design and construction of RW storages and repositories (final disposal facilities)
- Treatment of secondary RW produced during NPP decommissioning activities
- RW storage monitoring and decommissioning

Decommissioning

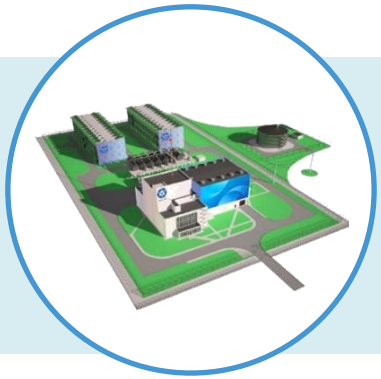
- NPP decommissioning strategy elaboration
- Fund concept elaboration aimed at future financing of NPP decommissioning
- NPP decommissioning planning
- NPP decommissioning up to “brownfield” or “greenfield”

Rosatom offers a flexible SMR solution

Aside from the vast experience in **design**, **manufacturing, construction** and **operation** for large-scale NPPs, **ROSATOM** also boasts an impressive record of **small reactor technology** development for the icebreaker fleet – more than **350** reactor-years!

ROSATOM is prepared to offer a flexible, tailor-made SMR solution, which can be fitted to partner's most specific needs.

ONSHORE



- On-ground power units

Technology: **RITM-200**

SMR

OFFSHORE

- Coastal territories
- Offshore installations

Technology: **RITM-200M / KLT-40S***

** applicable only to FNPP "Akademik Lomonosov"*

Flagship onshore SMR solution: RITM-200 – a highly reliable and efficient power source

ROSATOM

SMALL NUCLEAR POWER PLANT WITH RITM-200 UNITS IS A FITTING SOLUTION TO SUPPLY POWER IN A TIMELY MANNER AT AN AFFORDABLE COST TO THE CONSUMER.

ASIDE FROM THE **ENERGY SOLUTION** ROSATOM IS KEEN TO OFFER A WIDE RANGE OF RELATED PRODUCTS AND SERVICES

Fuel supply throughout the whole lifecycle

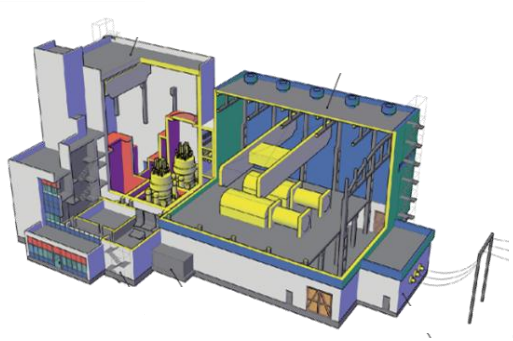
Comprehensive **spent nuclear fuel** and **radioactive waste management** solution

Human resources training and development

Engineering consulting in NPP **management** and **maintenance**

Long-term **service** and **maintenance** and **spare-parts** supply

Onshore RITM-200 – based NPP solution



Key NPP design features

TECHNOLOGY	RITM-200
Number of modules	2 with the possibility of further extension
Thermal capacity	> 350 MW(t)
Electric capacity	> 100 MW(e)
Average fuel enrichment	< 20%
Fuel campaign	5-7 years
Total efficiency	26%
Operating life	60 years
Capacity factor	98%

AKADEMIK LOMONOSOV FNPP

ROSATOM

AKADEMIK LOMONOSOV

COMMISSIONING DATE:
2019

FNPP

Currently under constriction at the Baltic Shipyard (Saint Petersburg)

FLOATING NUCLEAR POWER PLANT

is designed to supply electricity, thermal power, and desalinated water to coastal or isolated territories, offshore installations, islands, and archipelagoes.

Capacity (e)	77 MW (2 x 38.5)
Capacity (th)	300 MW
Thermal power with electric power reduced to 58%	146 Gcal/h
Length	140 m
Beam	30 m
Draft	5.6 m
Displacement	21,000 t
Fuel Campaign	3-5 years
Lifecycle	40 years (up to 50 years)
Mobility	Towed

FNPP Lifecycle

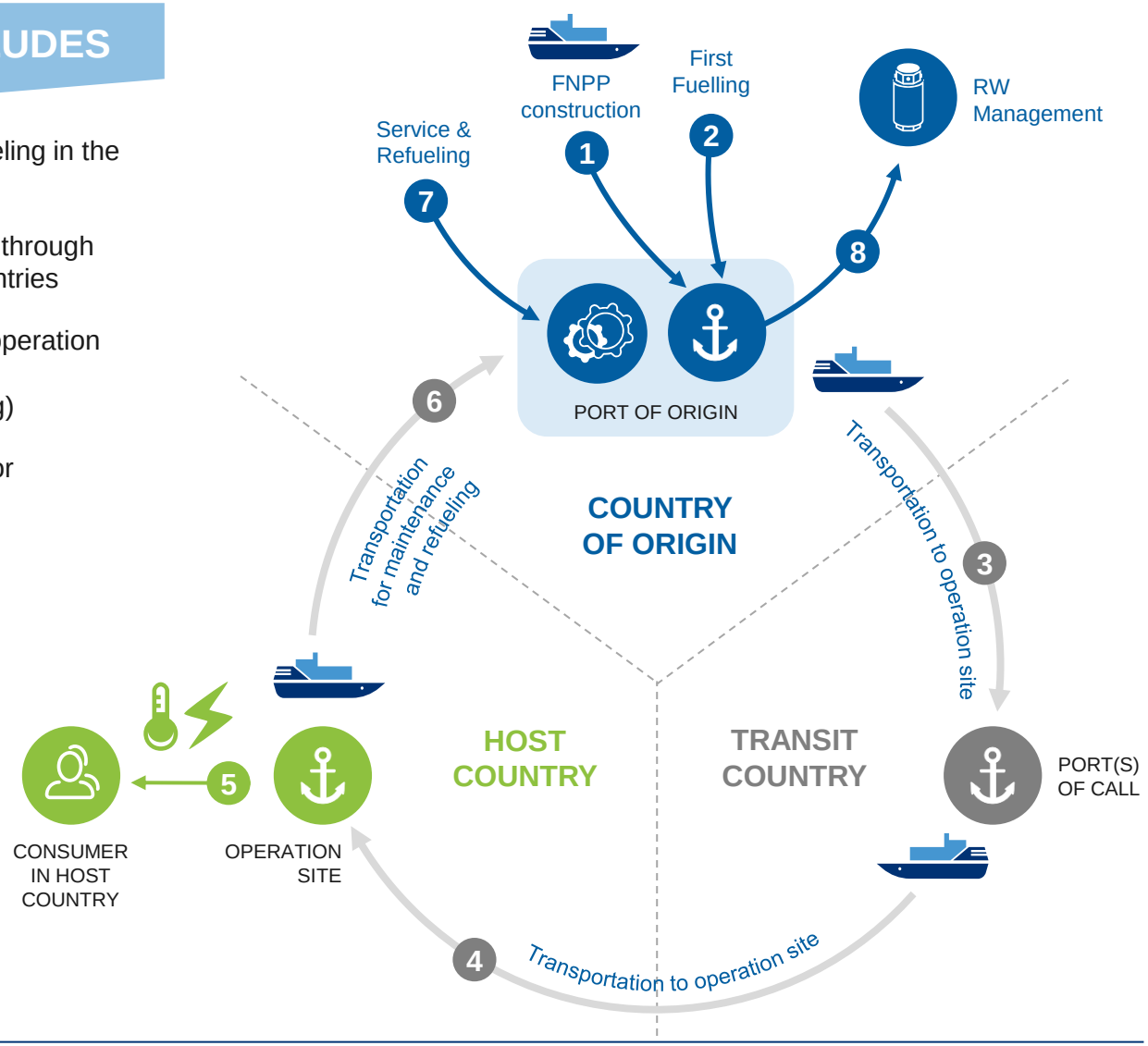
FNPP LIFECYCLE INCLUDES

- 1 2 FNPP construction and first fueling in the country of origin
- 3 4 transportation to operation site through the territorial sea of transit countries
- 5 power and heat production at operation site in host country (up to 10 years before refueling)
- 6 return to the country of origin for maintenance and refueling
- 7 Maintenance and refueling in the country of origin
- 8 RW Management in the country of origin
- 9 return to operation site

FNPP LIFE CYCLE

40-60

YEARS



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