TOMSK POLYTECHNIC UNIVERSITY

NUCLEAR POWER PLANTS
TOPIC: INTRODUCTION

LECTURERS

- Slyusarskiy Konstantin Vitalievich
  - Lectures and practices

CURRICULUM (2 SEMESTER)

- Lectures 32 hours;
- Practical classes 32 hours;
- Laboratory classes 16 hours;
- Classroom studies 80 hours;
- Self-study 80 hours;
- Total 160 hours.

RECOMMENDED SOURCES

- Power plant engineering/by Black & Veatch; Lawrence F. Drbal, managing editor, Patricia Boston, associate editor, Kayla L. Westra, associate editor.
- Nuclear Power Plants. Design and Safety Considerations / editor by J. P. Argyriou. — New York: Nova Science Publishers, Inc., 2012.
- Leyzerovich, Alexander. Wet-Steam Turbines for Nuclear Power Plants / A. Leyzerovich. — Tulsa: PennWell, 2005.
- Nag, P. K. Power Plant Engineering Third Edition. — Dept. of Mechanical Engineering, Kharagpur, 2008.
- Thermodynamics in Nuclear Power Plant Systems/ by Bahman Zohuri, Patrick McDaniel, Springer Cham Heidelberg New York Dordrecht London
- Handbook of Nuclear Engineering/ by Dan Gabriel Cacuci, Institute for Nuclear Technology and Reactor Safety

CONTENT

- Subject matter
- State and prospects of Nuclear Power
- Types of power plants
- NPP classification

CLASSIFICATION OF POWER PLANTS

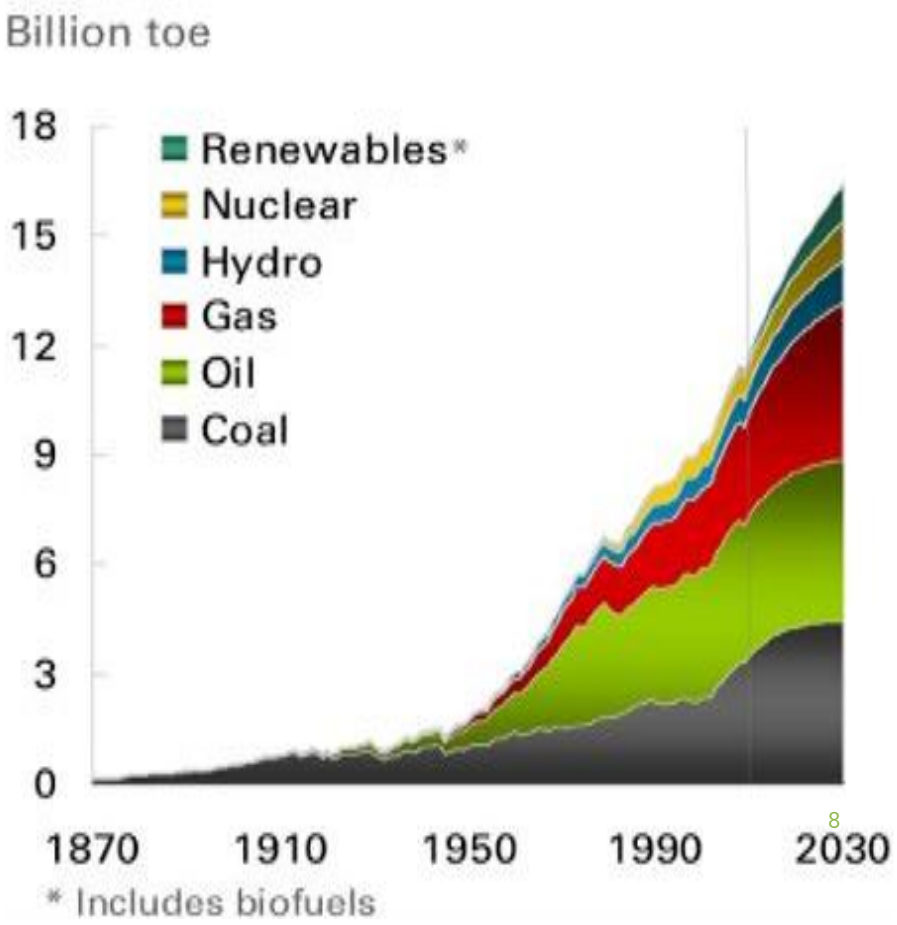
- Conventional
  - Thermal Power Stations
  - Nuclear Power Plants
  - Hydro-Electric Power Plants
- Non-conventional
  - Solar Power Plants
  - Wind Energy Power System
  - Wave and Tidal Wave Station

NUCLEAR POWER PLANT

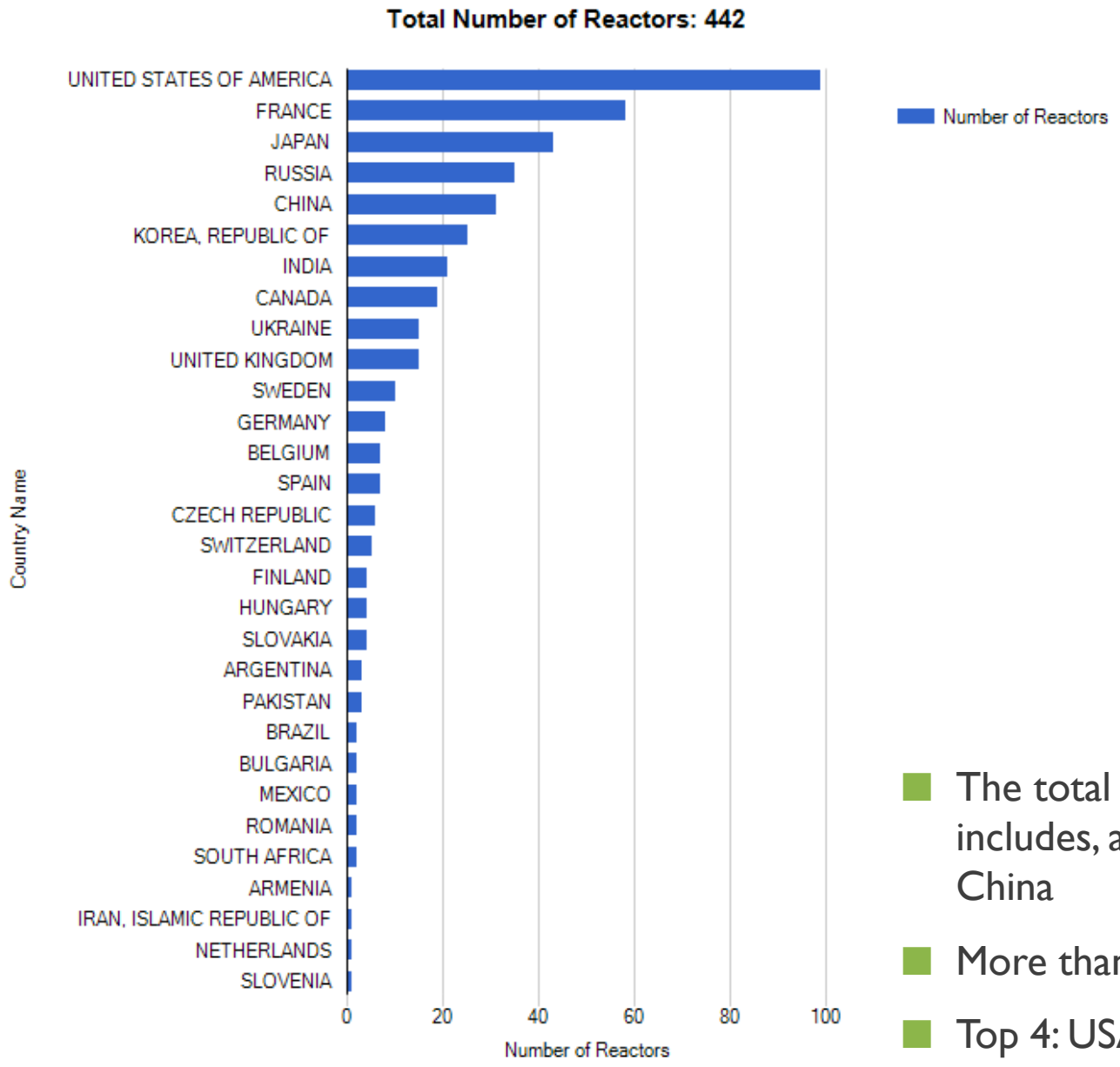
- A nuclear power plant is a facility for the production of electricity using nuclear energy

WORLD ENERGY CONSUMPTION

- Nuclear energy part is increasing
- Fossil fuels energy part is decreasing
- TOE - Tonne Oil Equivalent



CURRENT STATE AND DEVELOPMENT PROSPECTS OF THE WORLD NUCLEAR POWER

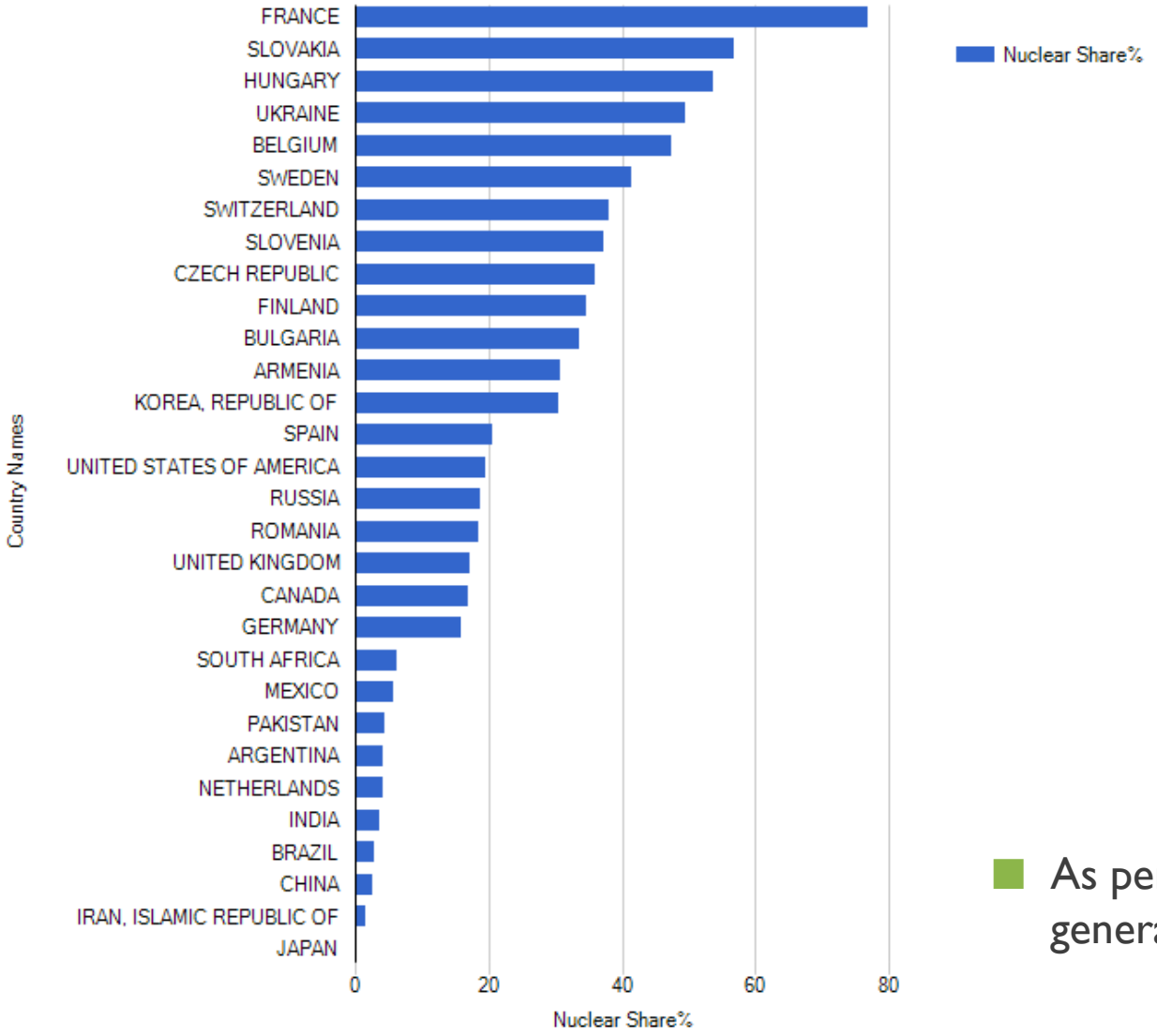


- The total Number of Reactors includes, also 6 reactors in Taiwan, China
- More than 30 countries
- Top 4: USA, France, Japan, Russia

LEADERS IN NUCLEAR POWER

Country	Installed nuclear capacity, GW	Nuclear power share in electricity generation, %
USA	102 (99 Reactor Units)	19,5
France	63 (58 R.U.)	76,9
Japan	40 (43 R.U.)	30,0
Russia	25 (35 R.U.)	18,6
Korea	25 (23 R.U.)	30,4
China	27 (31 R.U.)	2,4

NUCLEAR SHARE OF ELECTRICITY GENERATION IN 2014

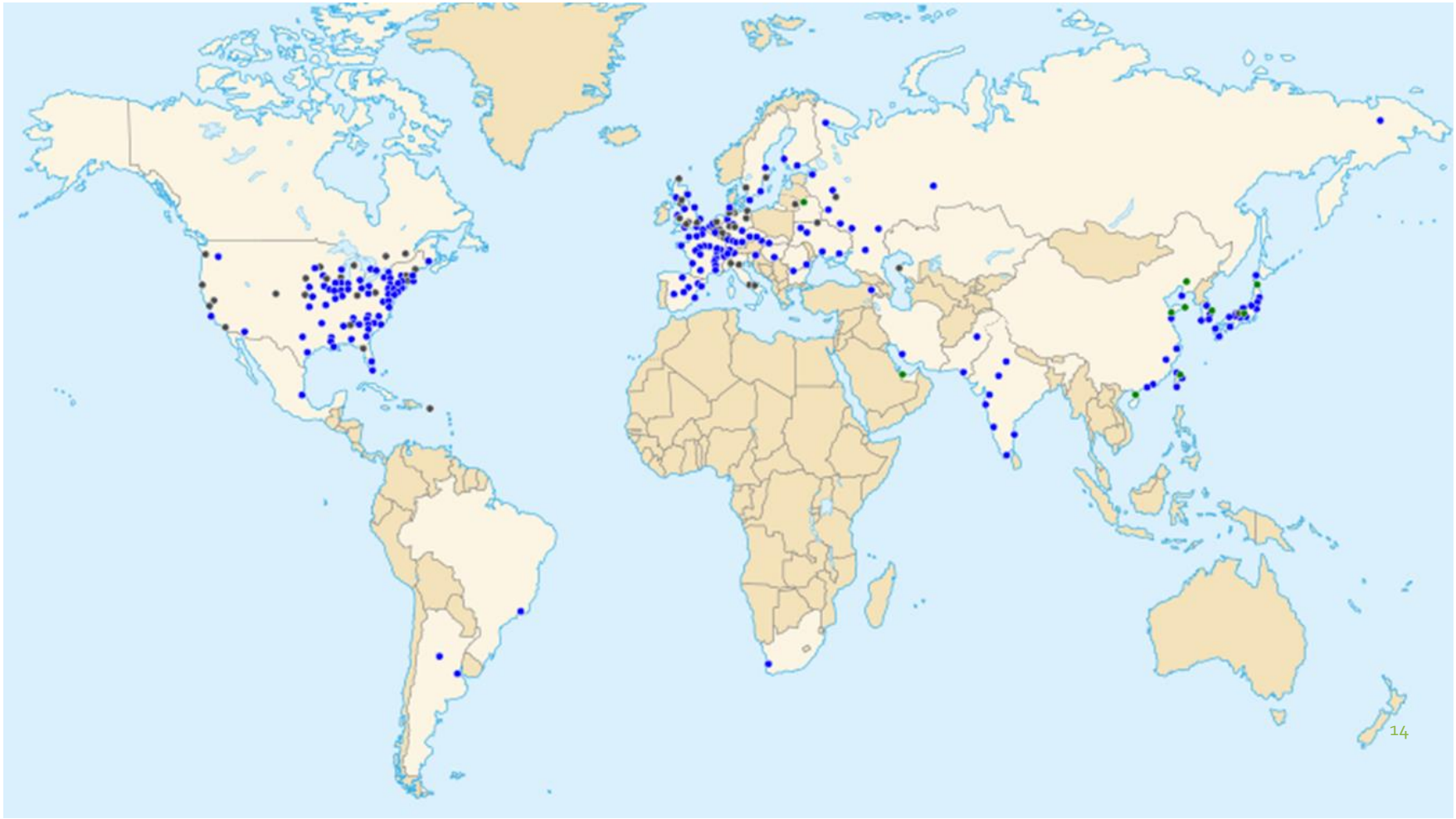


- As percentage of electric energy generation in country

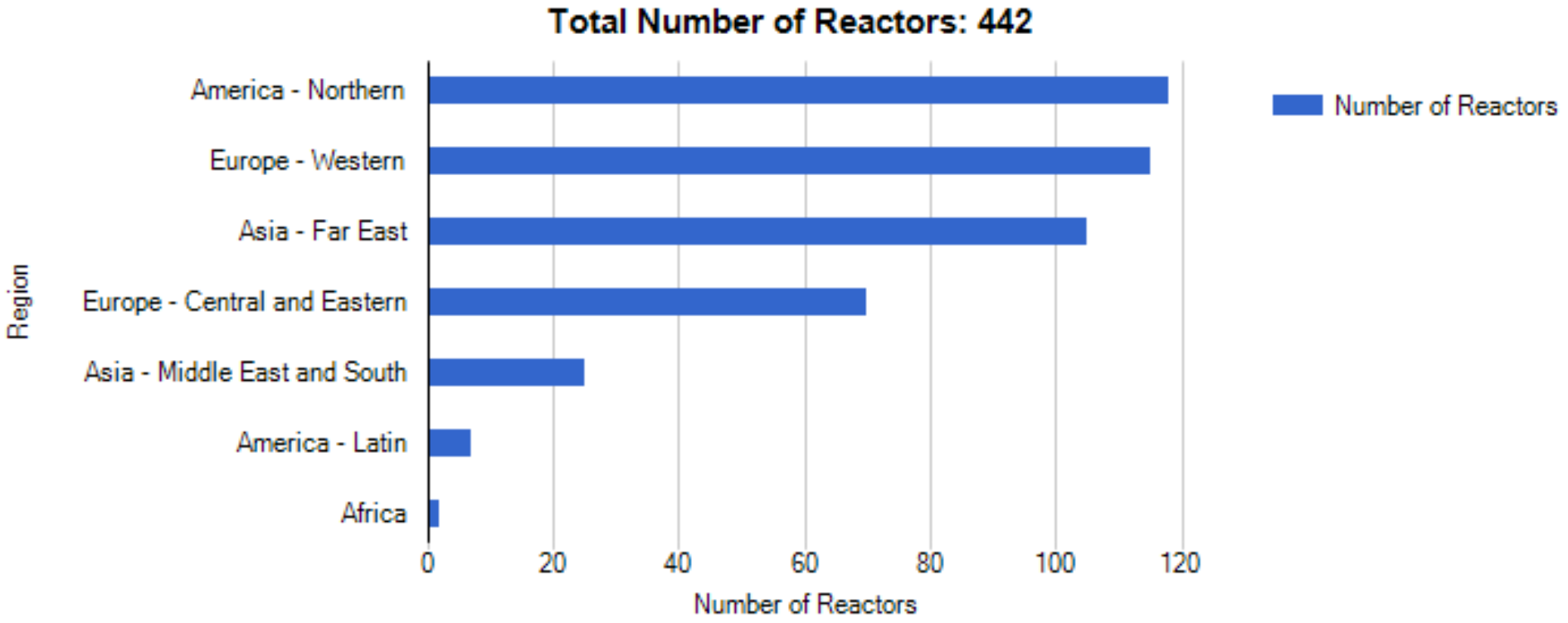
THE LARGEST NUCLEAR POWER PLANTS

Rank	Station	Country	Number of units	Capacity (GW)
1	Kashiwazaki-Kariwa	Japan	7	7,965
2	Bruce	Canada	8	6,232
3	Zaporizhia	Ukraine	6	6,000

LOCATION OF NPP



REACTORS ALLOCATION



NPP IN RUSSIA

THE LARGEST NPP IN RUSSIA

Station	# units	Capacity (MW)
Leningrad NPP	4	4000
Balakovsk NPP	4	4000 (+1)
Kursk NPP	4	4000 (+1)
Kalininsk NPP	4	4000 (+1)


БАЛАКОВСКАЯ АЭС


БЕЛОЯРСКАЯ АЭС


БИЛИБИНСКАЯ АЭС


КАЛИНИНСКАЯ АЭС


КОЛЬСКАЯ АЭС


КУРСКАЯ АЭС

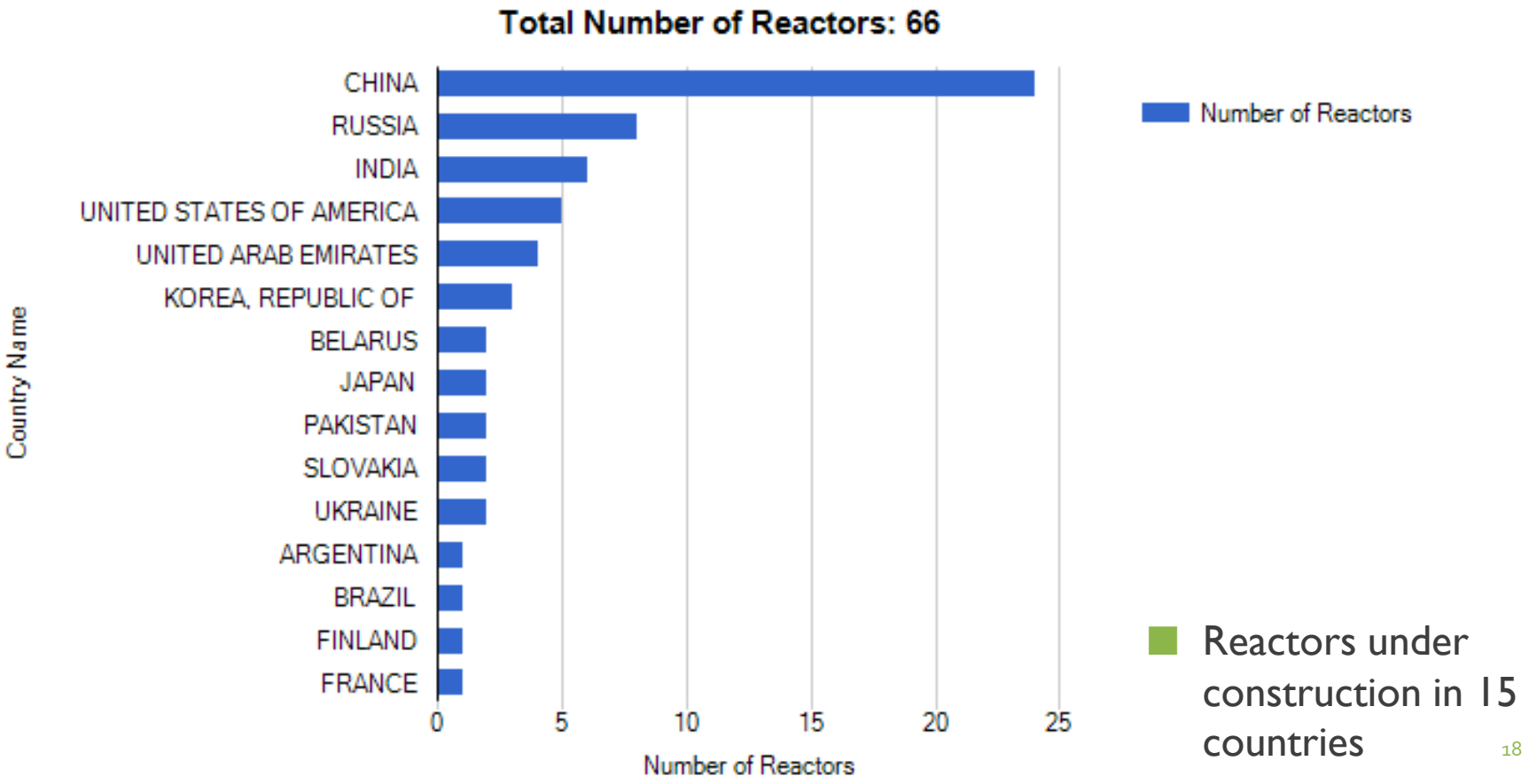

ЛЕНИНГРАДСКАЯ АЭС


НОВОВОРОНЕЖСКАЯ АЭС


РОСТОВСКАЯ АЭС


СМОЛЕНСКАЯ АЭС

REACTORS UNDER CONSTRUCTION

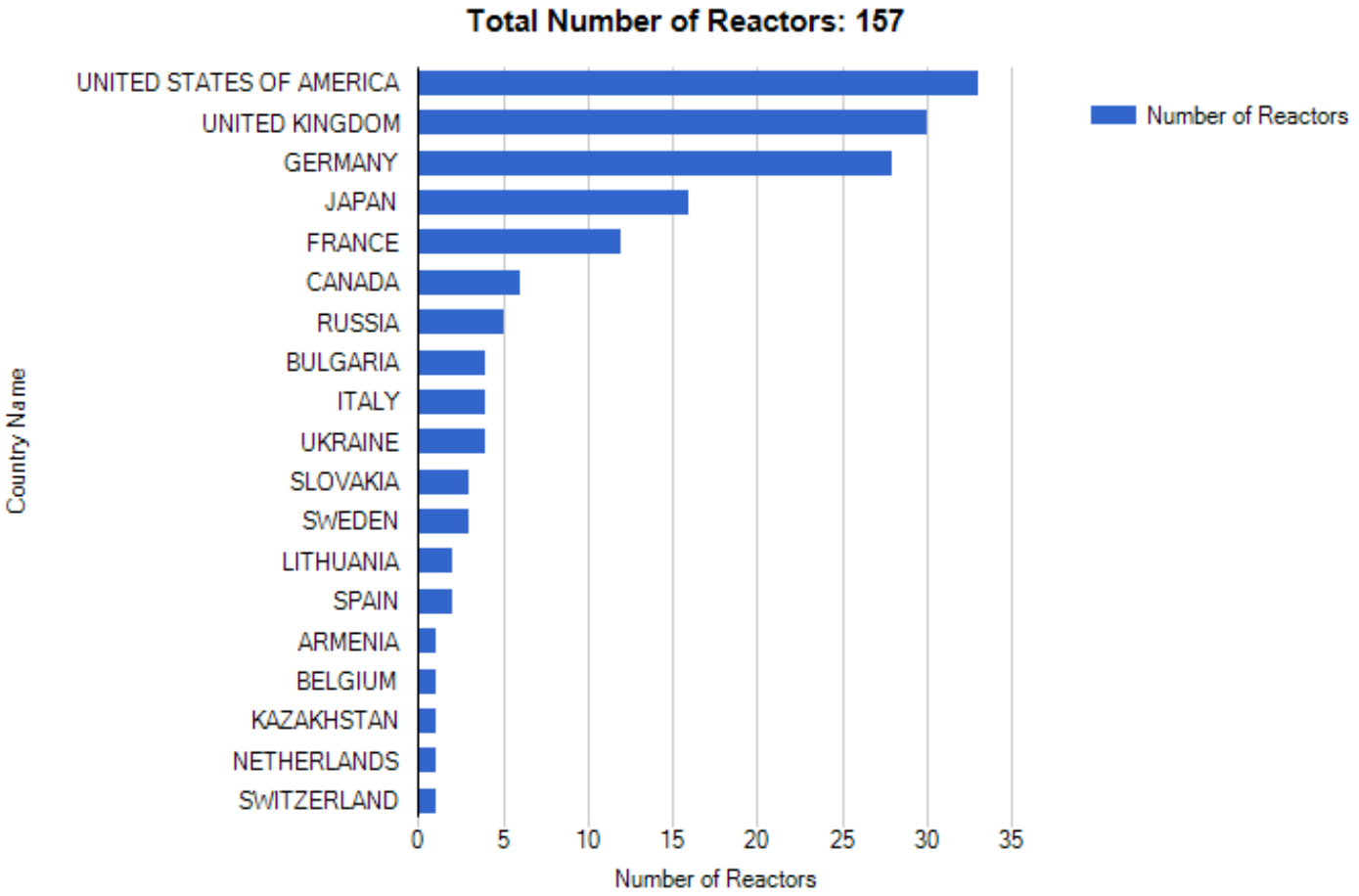


- Reactors under construction in 15 countries

REACTORS UNDER CONSTRUCTION

Country	Number of Reactors	Total Net Electrical Capacity [MW]
ARGENTINA	1	25
BELARUS	2	2218
BRAZIL	1	1245
CHINA	24	24128
FINLAND	1	1600
FRANCE	1	1630
INDIA	6	3907
JAPAN	2	1325
REPUBLIC OF KOREA	3	4020
PAKISTAN	2	630
RUSSIA	8	6582
SLOVAKIA	2	880
UKRAINE	2	1900
UNITED ARAB EMIRATES	4	5380
UNITED STATES OF AMERICA	5	5633
Total	**66**	**63703**

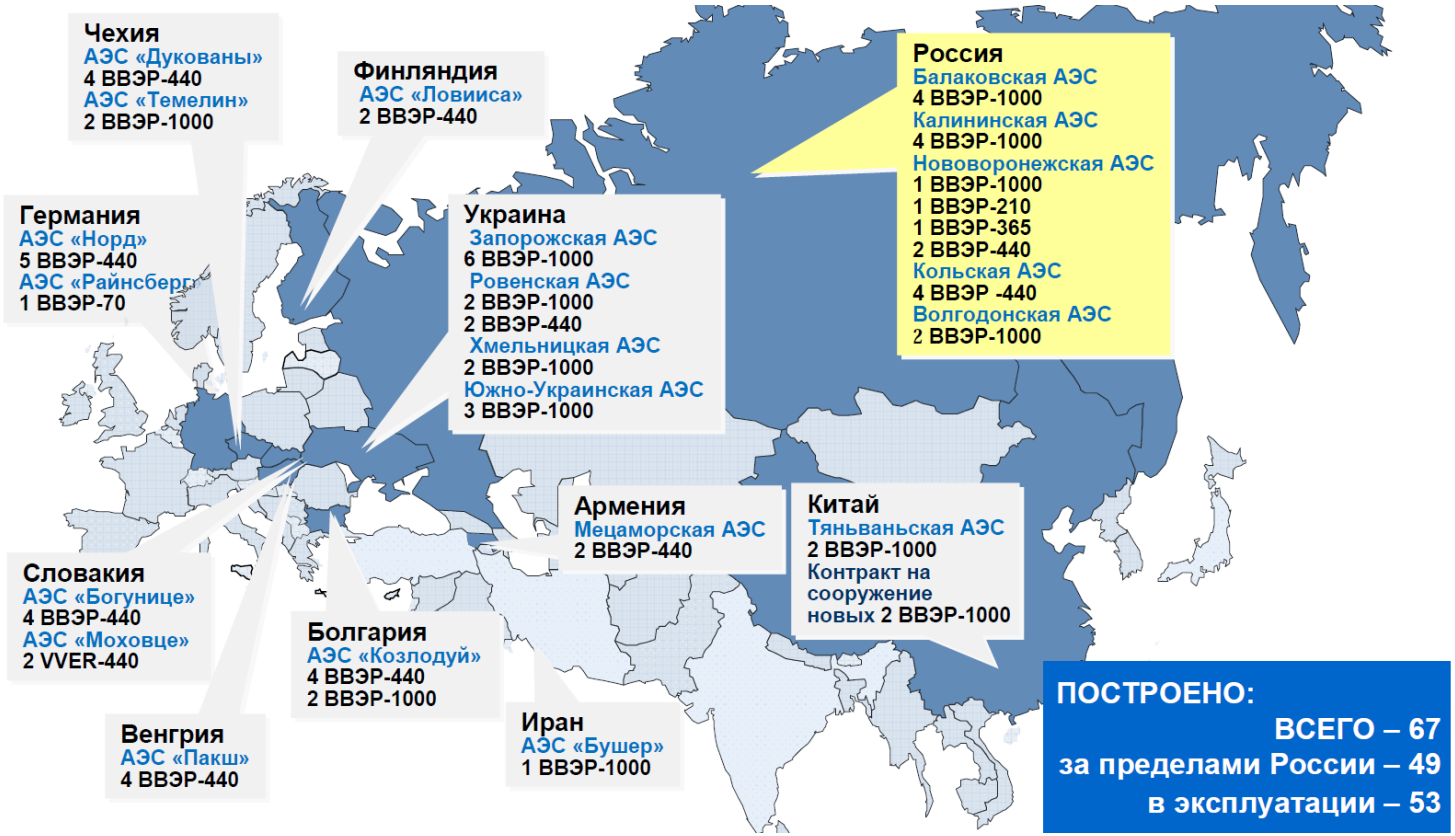
PERMANENT SHUTDOWN REACTORS



REACTOR TYPES

Reactor Type	Reactor Type Descriptive Name	Number of Reactors	Total Net Electrical Capacity [MW]
PWR	Pressurized Light-Water-Moderated and Cooled Reactor	283	264860
PHWR	Pressurized Heavy-Water-Moderated and Cooled Reactor		24551
LWGR	Light-Water-Cooled, Graphite-Moderated Reactor	15	10219
GCR	Gas-Cooled, Graphite-Moderated Reactor	14	7685
FBR	Fast Breeder Reactor	3	1369
BWR	Boiling Light-Water-Cooled and Moderated Reactor	78	74862
Total		**442**	**383546**

RUSSIAN REACTORS VVER

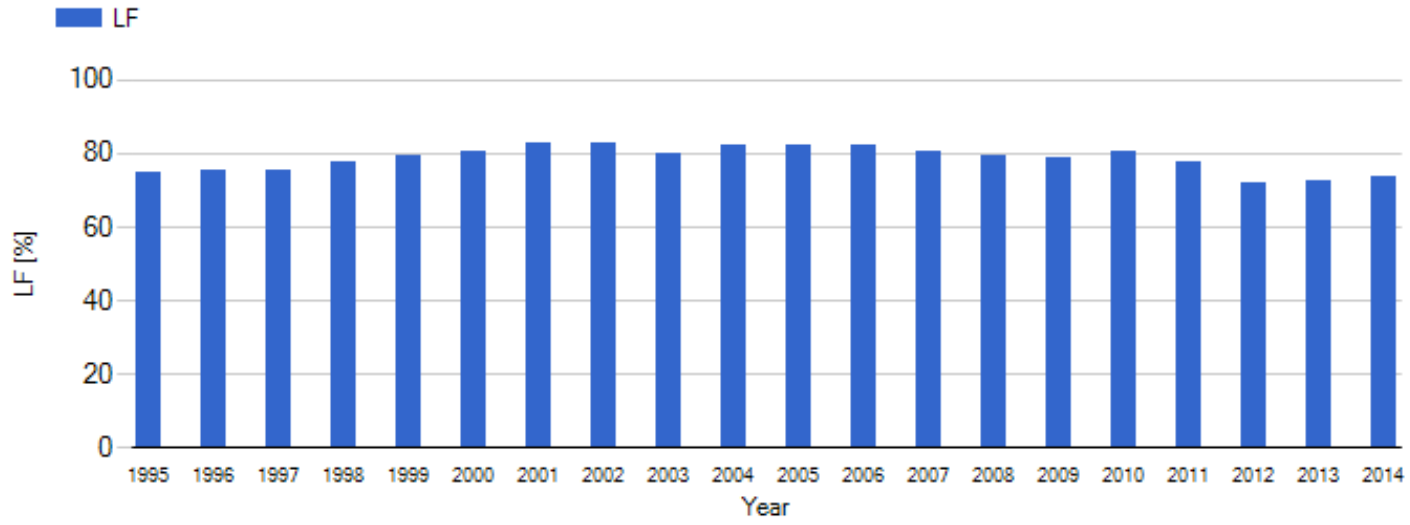


- PWR = VVER

ATOMIC ENERGY INDUSTRY DEVELOPMENT TRENDS

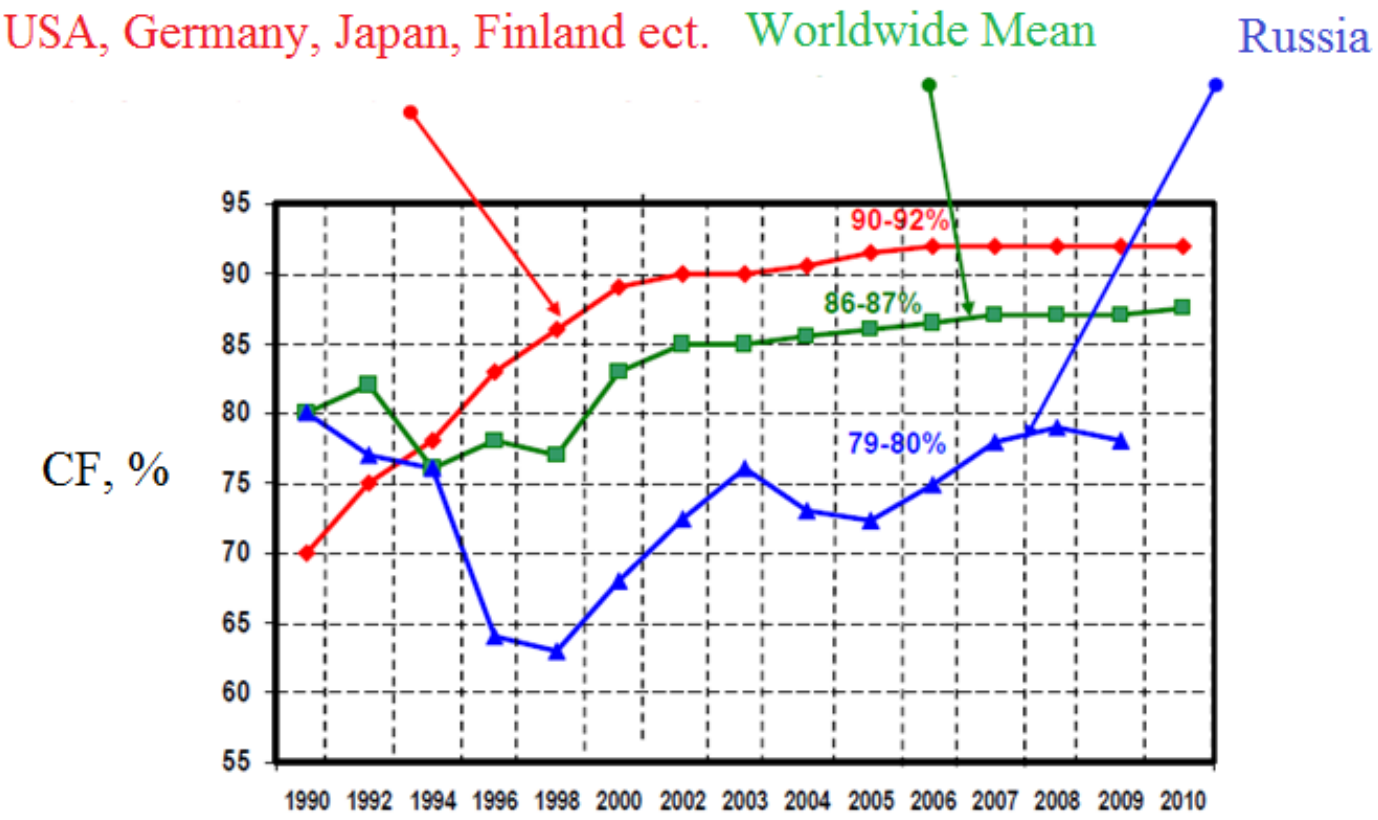
- The increase in the construction of new nuclear power plants in Asia
- Lifetime extension
- Increasing competitiveness
- Forming public opinion about nuclear power

LOAD FACTOR TREND OR CAPACITY FACTOR



- In electrical engineering the load factor is defined as the average load divided by the peak load in a specified time period.

LOAD FACTORS COMPARISON



RUSSIAN NPP CHARACTERISTIC

Characteristic	VVER-440	VVER-1000	RBMK-1000	BN-600	EGP-6
Thermal output, MW	1375	3000	3200	1470	62
Electrical output, MW	440	1000	1000	600	12
coolant pressure, MPa	12,3	15,7	6,9	-	6,2
Mass flow, ton / hr.	40800	84800	48000	25000	600
Throttle pressure, MPa	4,3	5,9	6,6	13,0	6,0
Fuel enrichment, %	3,6	4,3	2,0 – 2,4	17 – 33	3,0 – 3,6

RUSSIAN NPP UNDER CONSTRUCTION (DOMESTIC)

- **Beloyarsk NPP**
  Reactor type: BN-800 (fast neutron reactor)
  Power units: 1 (under construction)

- **Leningrad NPP-2**
  Reactor type: VVER-1200 (PWR)
  Power units: 2 (under construction) + 2 (planned for the future)

- **Novovoronezh NPP-2**
  Reactor type: VVER-1200 (PWR)
  Power units: 2 (under construction) + 2 (planned for the future)

- **Akademik Lomonosov floating NPP**
  Reactor type: KLT-40S
  Power units: 2

- **Rostov NPP**
  Reactor type: VVER-1000
  Power units: 2 (in operation) + 2 (under construction)

NPPS UNDER CONSTRUCTION IN FOREIGN COUNTRIES

- **BELARUS**
  Construction of Belarusian NPP
  Project specifications: 2 power units with VVER-1200 (PWR) reactors.

- **TURKEY**
  Stage 1 construction of Akkuyu NPP
  Project specifications: 4 power units with VVER-1200 (PWR)

- **INDIA**
  Stage 1 construction of Kudankulam NPP
  Project specifications: the first power unit with 1,000 MW VVER-1000 (PWR) reactor.

- **VIETNAM**
  Construction of 2 power units at Ninh Thuận 1
  Project specifications: 2 power units with 1,000 MW VVER-1000 (PWR) reactors.

- **BANGLADESH**
  Preparation for construction of Ruppur NPP, the country's first nuclear power plant
  Project specifications: Construction of two power units with VVER reactors.

- **CHINA**
  Stage 2 construction of Tianwan NPP (power units 3 and 4)
  Project specifications: Two more power units with VVER-1000 reactors (2,100 MW total capacity) are currently under construction.

RUSSIAN NUCLEAR POWER INDUSTRY (LIFETIME EXTENSION)

- Currently, lifetime of 9 units in the concern "Rosenergoatom" were extended:
  - four units of Bilibino NPP
  - the third and fourth units of Novovoronezh NPP;
  - the first and second blocks Kola NPP
  - the first unit of Leningrad NPP
- Prepare documents for the extension of the operation of the second unit of Leningrad NPP and the first unit of Kursk NPP

NPP PROS AND CONS

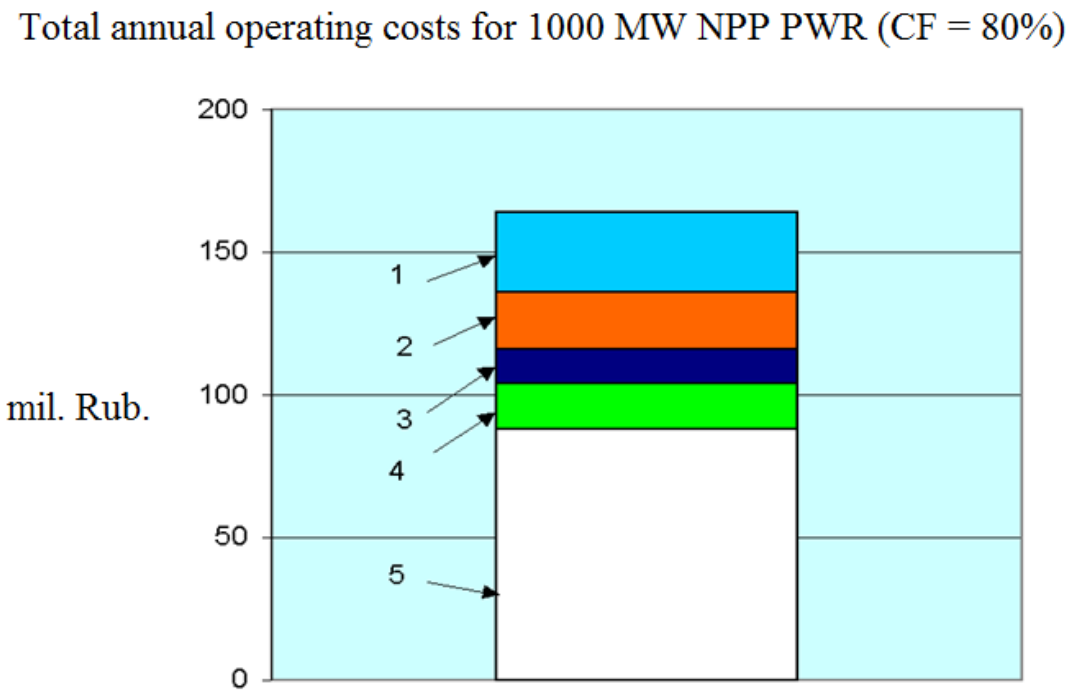
- Environmental friendliness
- Relative cheapness of fuel
- Relatively high unit cost
- Long duration of construction
- Expensive decommission
- Necessity in closed fuel cycle

ENVIRONMENTAL FRIENDLINESS

- Absence of "greenhouse effect"
- No chemical releases into the environment

RELATIVELY CHEAP FUEL

1. Fuel expanses (including long-term away-from-reactor store)
2. Other expanses
3. Taxes
4. Additional investments
5. Operating and support expanses



COMPARISON PRICES FOR ELECTRICITY BETWEEN TPP AND NPP

Country	Year of commissioning				
	1990	1995	1995-2000	2005	2010
Canada	1,42	1,44	1,33	1,27	1,14
FRG	1,64	1,68	1,42	1,3	1,52
France	1,75	1,8	1,45	1,44	1,54
Japan	1,51	1,37	1,28	1,24	1,18
Great Britain	1,43	1,4	1,06	-	0,98
USA	1,01	0,83	0,91	-	1,04

NPP REQUIREMENTS

- Safety and Security
  - overall
  - radiation
  - nuclear
- Quality and Reliability
  - 50 ± 0,1 Hz
  - tSV ± 0,1 0C
- Economy

QUALITY ENHANCEMENT OF NPP OPERATION

- For the past 10 years
  - CF was increased from 76 to 85%
  - Number of emergency shutdowns were decreased from 1,8 to 0,7 unit per year
  - Population radiation dose decreased from 170 to 100 rem / unit per year

NPP CLASSIFICATION

- Functional purpose
  - Nuclear power plant NPP
  - Nuclear heat and power plant NHPP
  - Nuclear heating plant NHP
- Number of circuits
- Type of reactor
- Type and parameters of turbines
- On the use of power

ENERGY USAGE

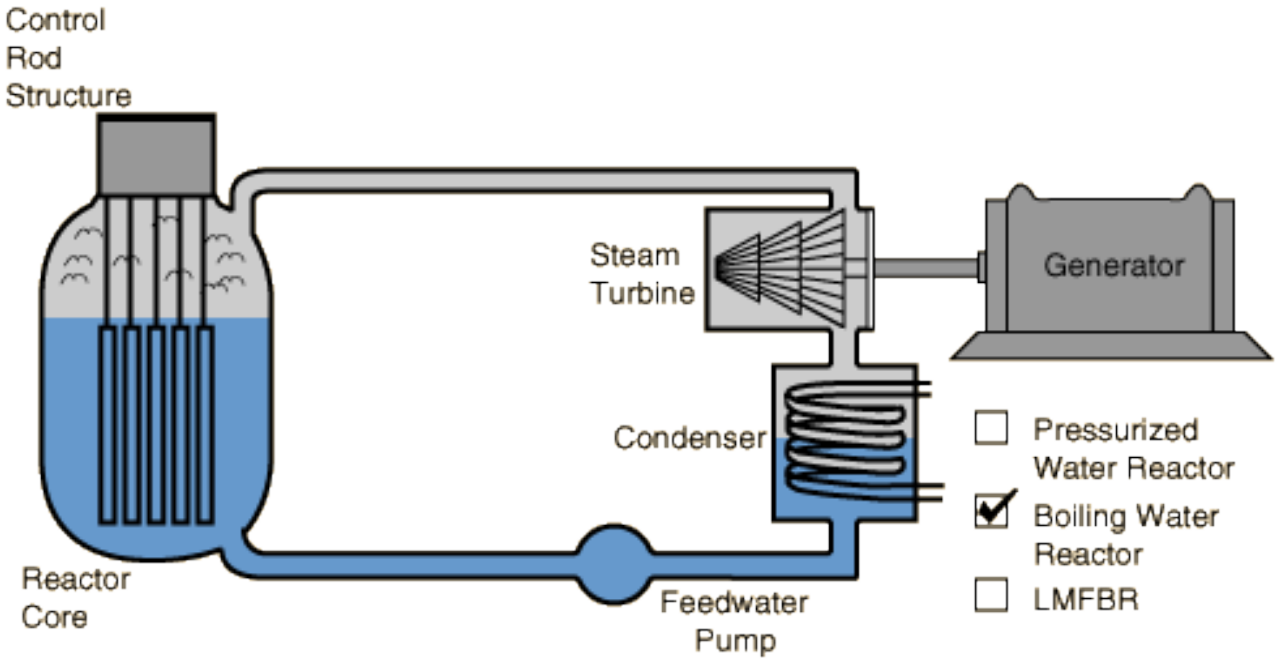
- Base load — $T_{Inst.} > 5000$ h / year
- Intermediate load — $T_{Inst.} = 3000\text{-}4000$ h / year
- Peak load — $T_{Inst.} < 1500$ h / year

NUMBER OF CIRCUITS

- One-circuit
  - BWR
  - RBMK
  - EGP
- Two-circuit
  - PWR
  - VVER
- Three-loop circuit
  - BN (FBR)

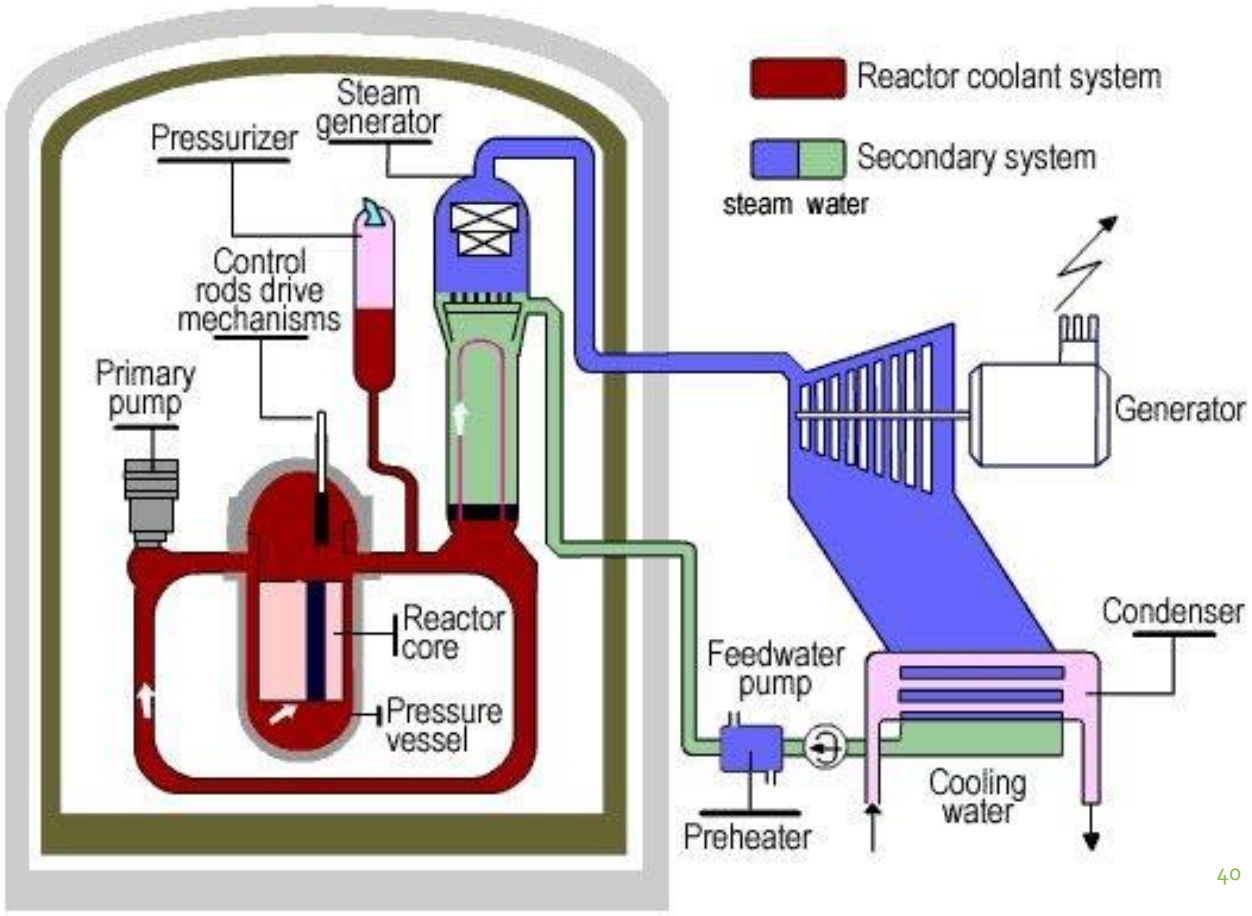
ONE-CIRCUIT NPP DIAGRAM

- BWR
- RBMK
- EGP



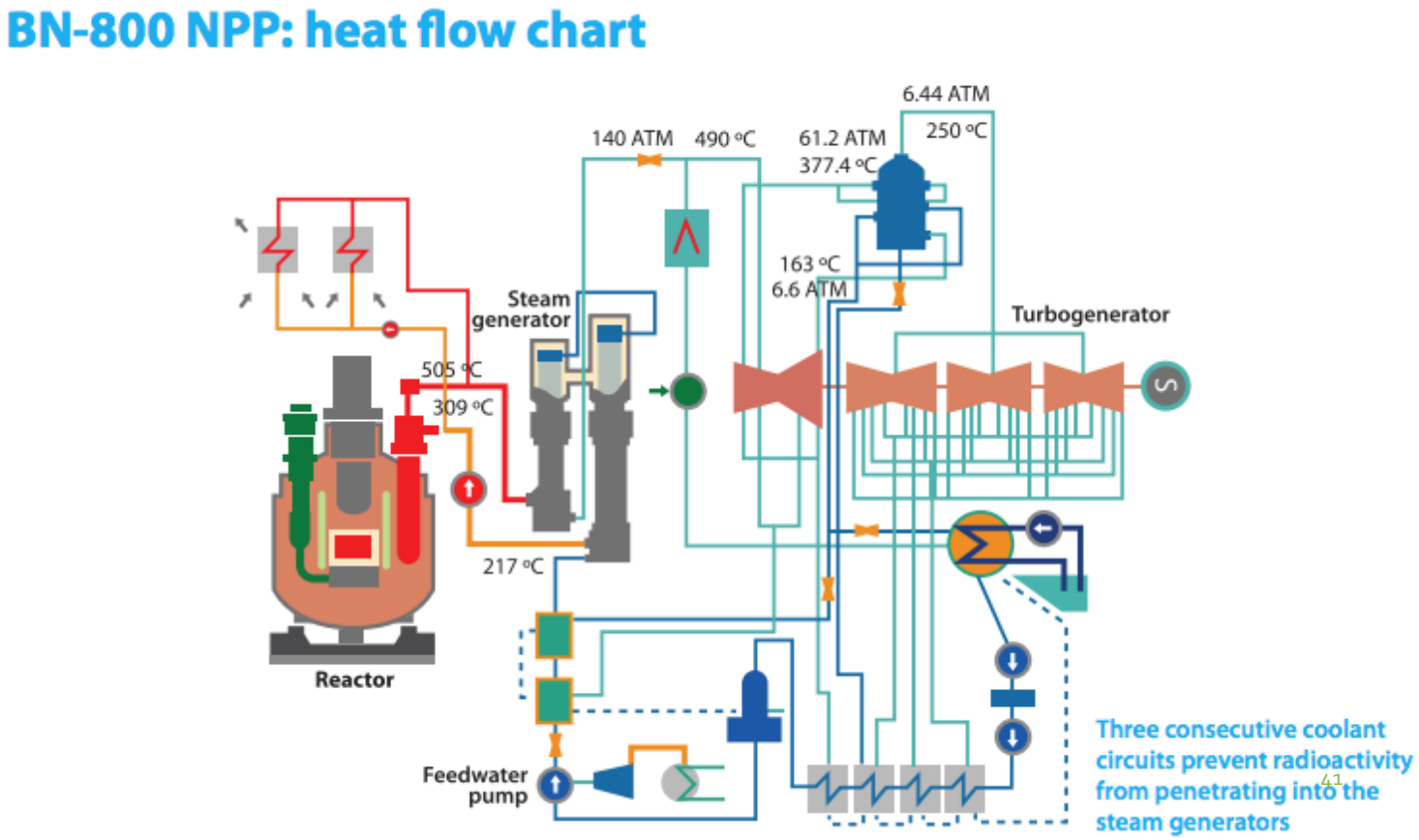
TWO-CIRCUITS NPP DIAGRAM

- PWR
- VVER



THREE-LOOP NPP DIAGRAM

- BN
- Fenix



ONE-CIRCUIT NUCLEAR POWER PLANT

- Advantages:
  - circuit simplicity
- Disadvantages:
  - radioactive coolant
  - low thermal efficiency
  - poor dynamic properties

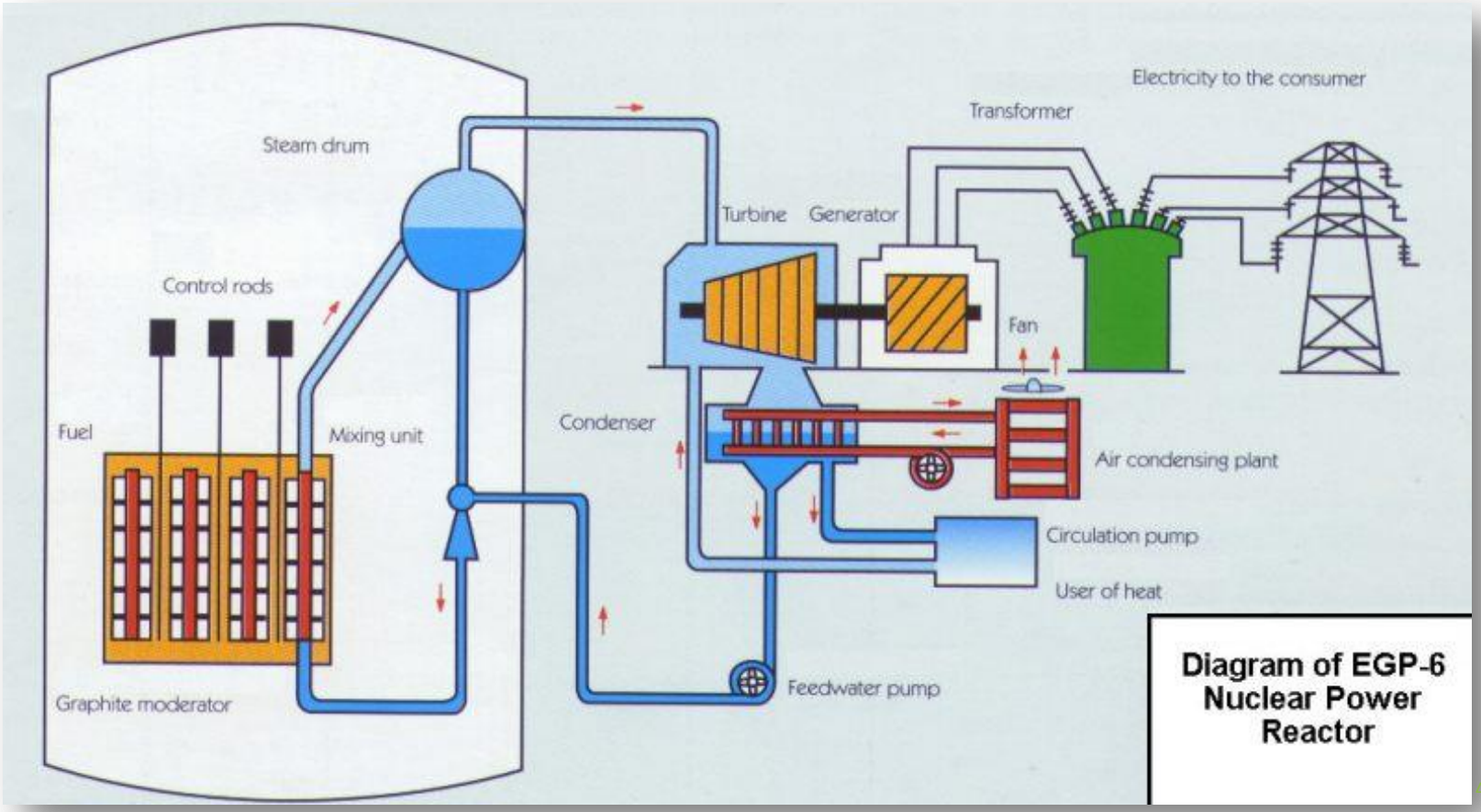
TWO-CIRCUIT NUCLEAR POWER PLANT

- Advantages:
  - secondary coolant is not radioactive
  - satisfactory dynamic properties
- Disadvantages:
  - circuit complexity
  - large capital cost
  - low thermal efficiency

THREE-LOOP NUCLEAR POWER PLANT

- Advantages:
  - working fluid is not radioactive
  - good dynamic properties
  - high thermal efficiency
- Disadvantages:
  - circuit complexity
  - large capital cost

NUCLEAR HEAT AND POWER PLANT NHPP



BILIBINSKAYA NPP

- Ne=48 MW
- Qt=78 MW

NUCLEAR HEATING PLANT NHP

- Features
  - The reactor is operated only at low temperatures
  - Relatively inexpensive materials
  - Simple regulation
  - In some cases, economical
  - Three-loop circuit

THANK YOU FOR YOUR ATTENTION