# Operation Experience of NPPs of JSC "Concern Rosenergoatom". Ensuring Safety and Enhancement of Efficiency of Russian Nuclear Power

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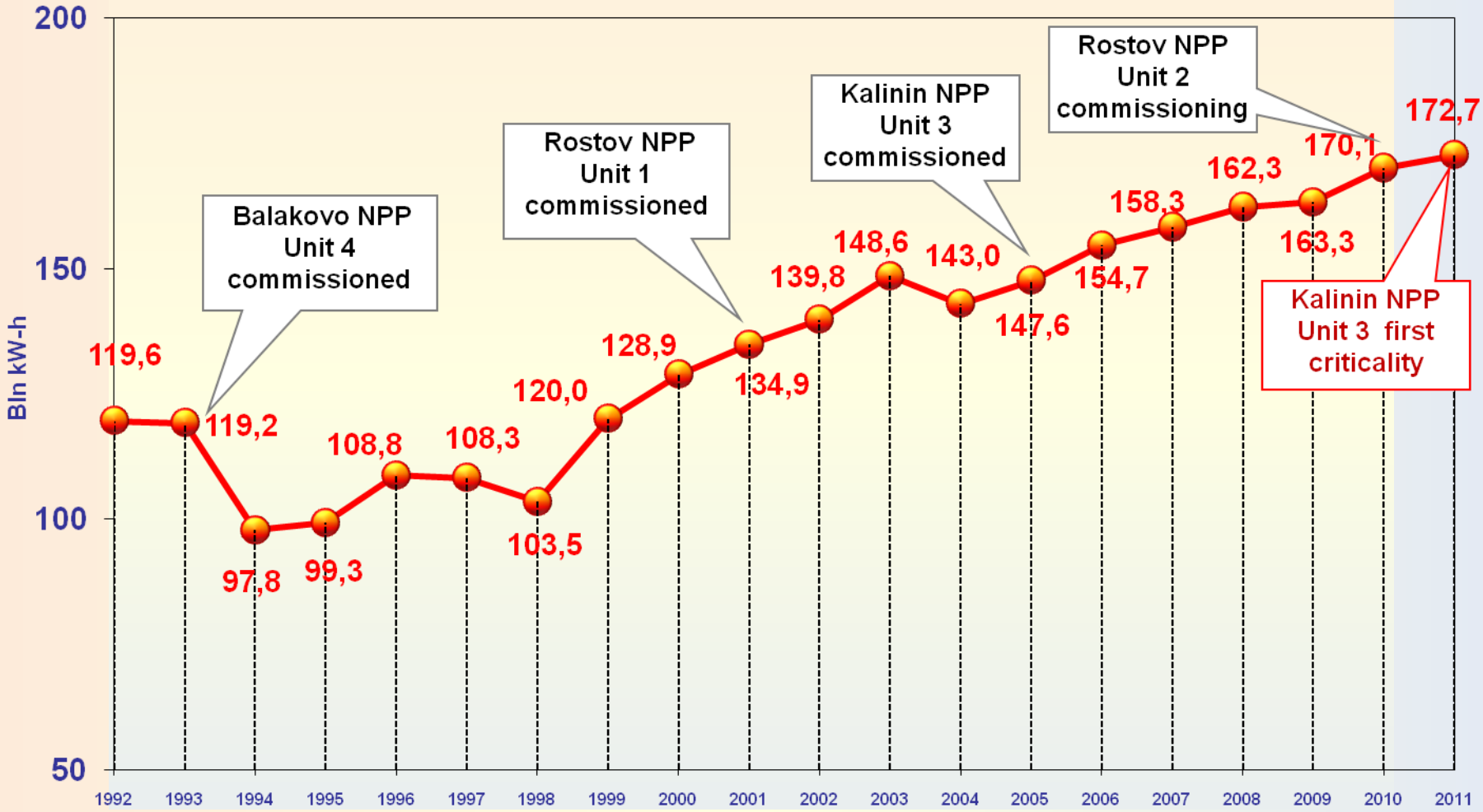
# The Operating Organization JSC "Concern Rosenergoatom"

- Rosenergoatom was established on 07.09.1992 as an Operating Organization by the RF President's Decree

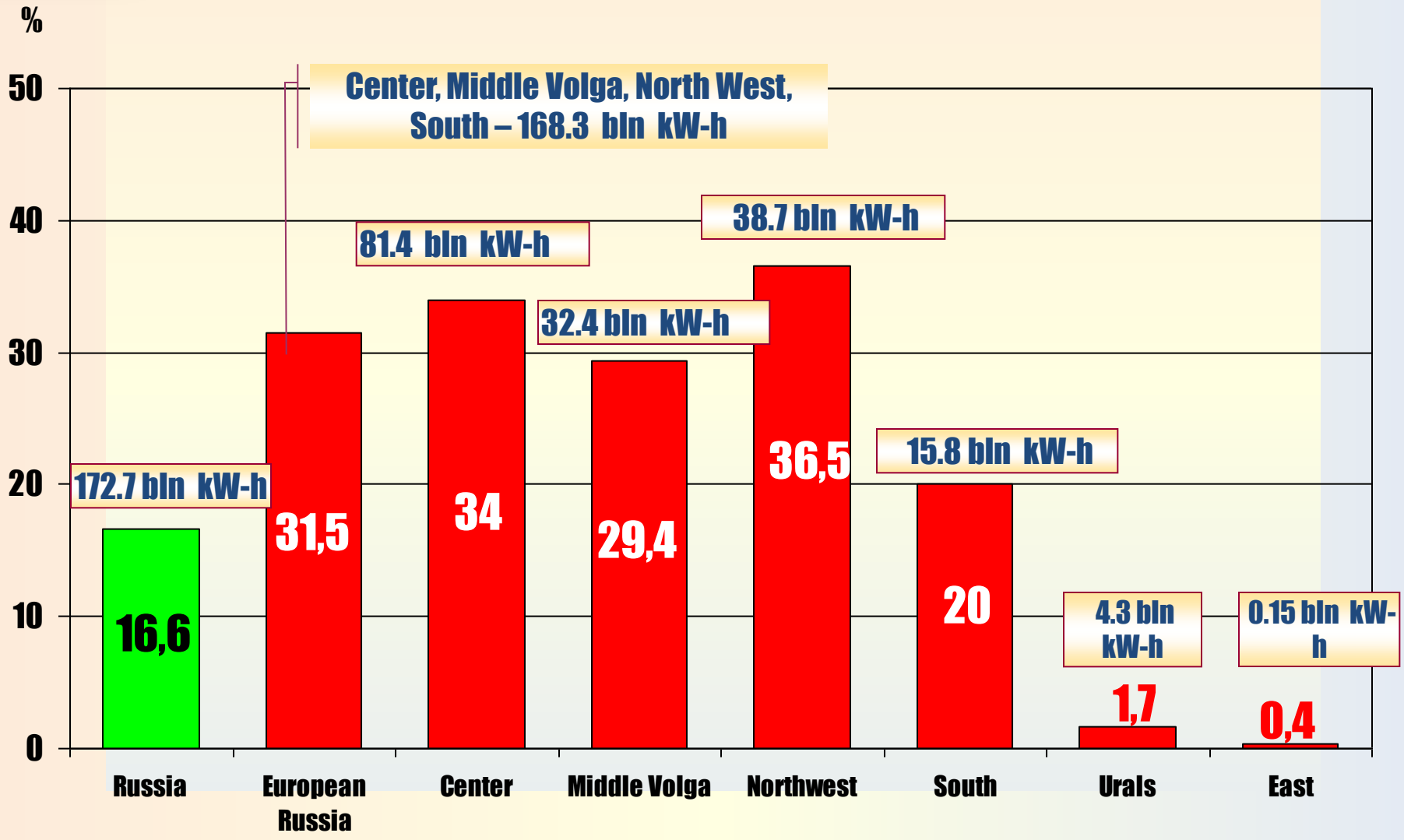
| | | |
|---|---|---|
| 33 | | number of existing power units |
| 25242 | MWt | the installed capacity |
| 172,7 | bln kW-h | generated in 2011 |
| 35 | thous. pers. | Rosenergoatom personnel size |
| 6 | bln $ | commercial output in 2011 |
| 283,9 | mln $ | R&D value in 2011 |

# Electricity generation by Russian NPPs

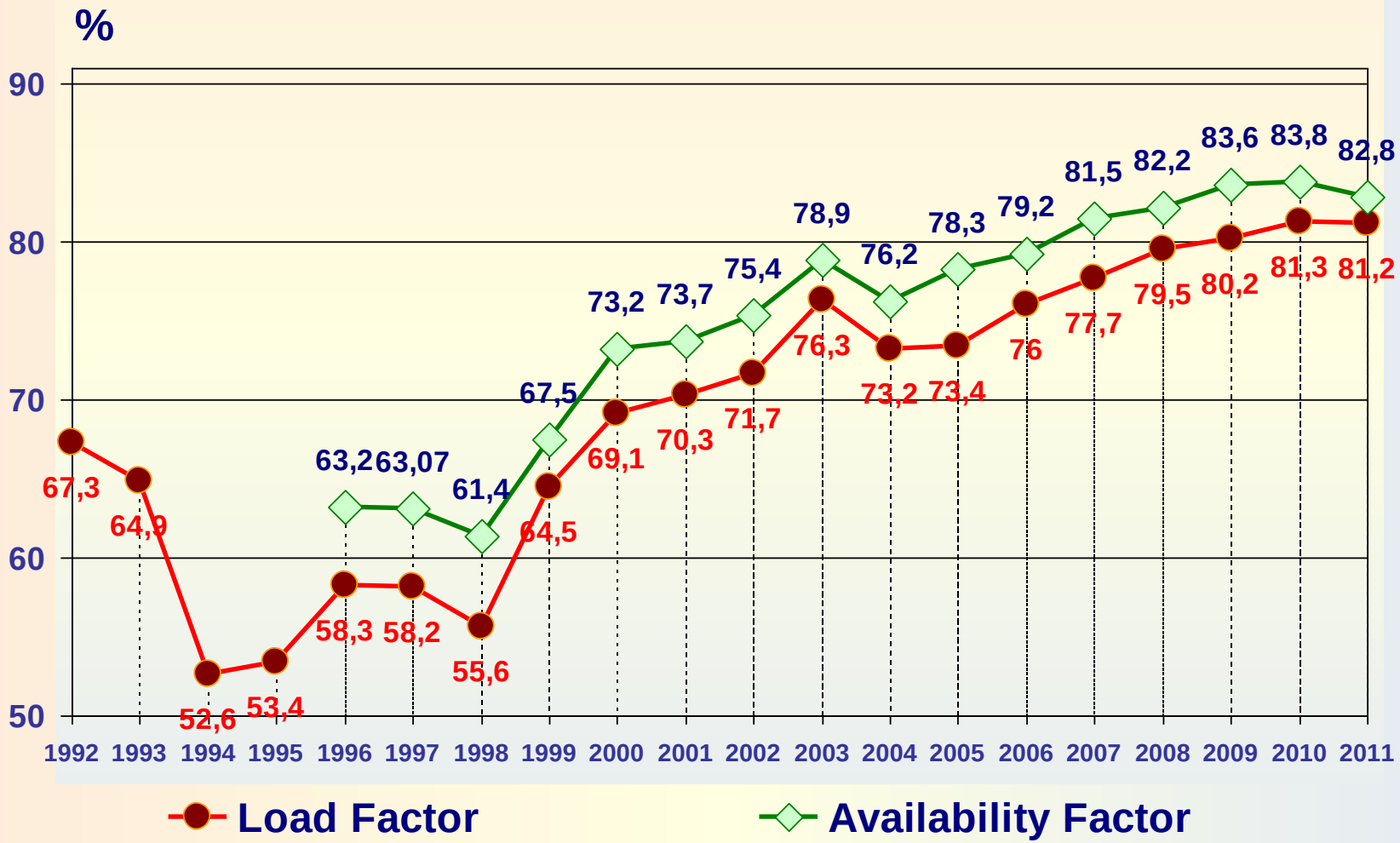
**(~ 16,6 % of total electricity generation)**



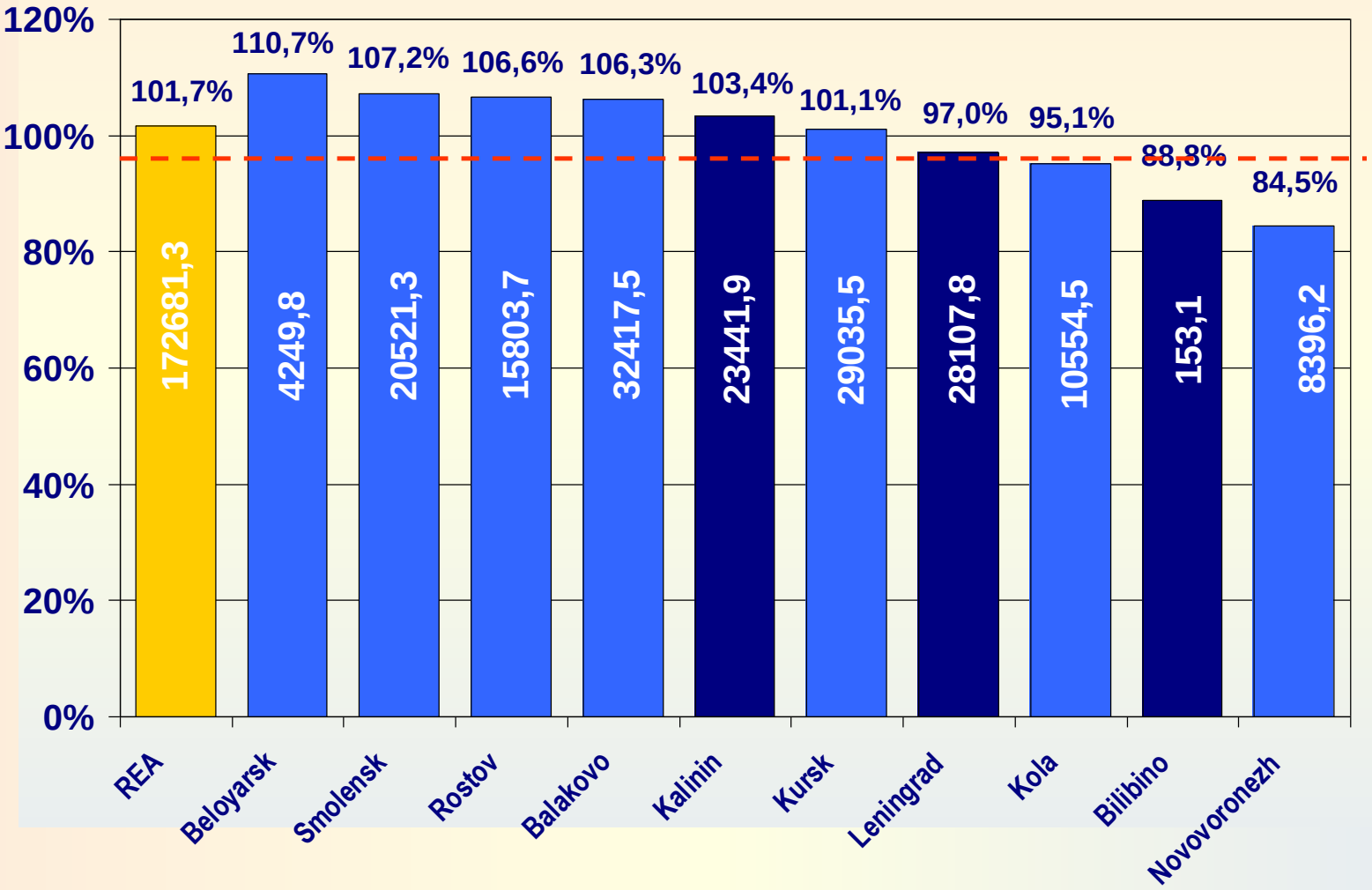
# Share of nuclear electricity generation by regions in 2011



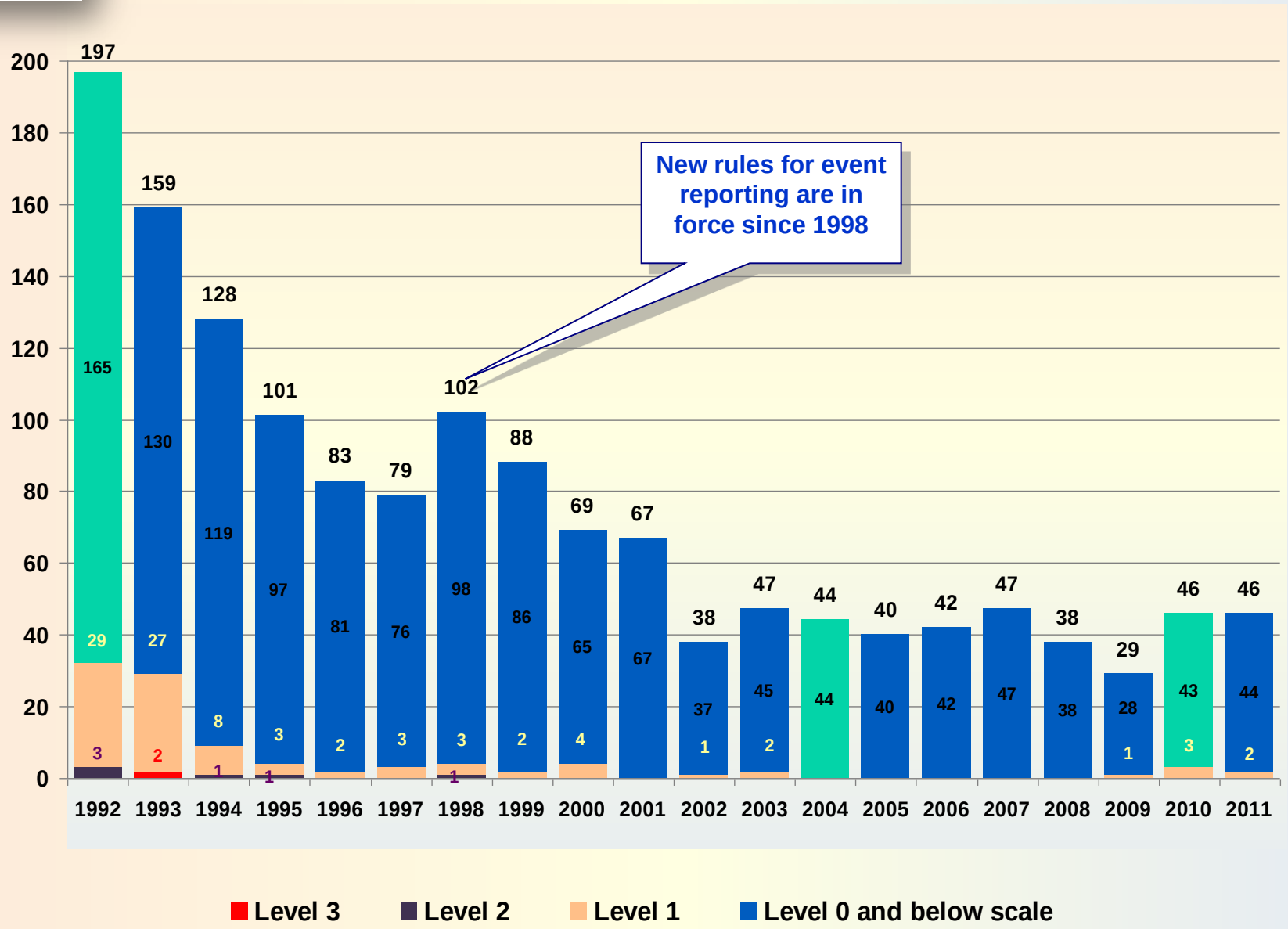
# Load Factor and Availability Factor of Russian NPPs



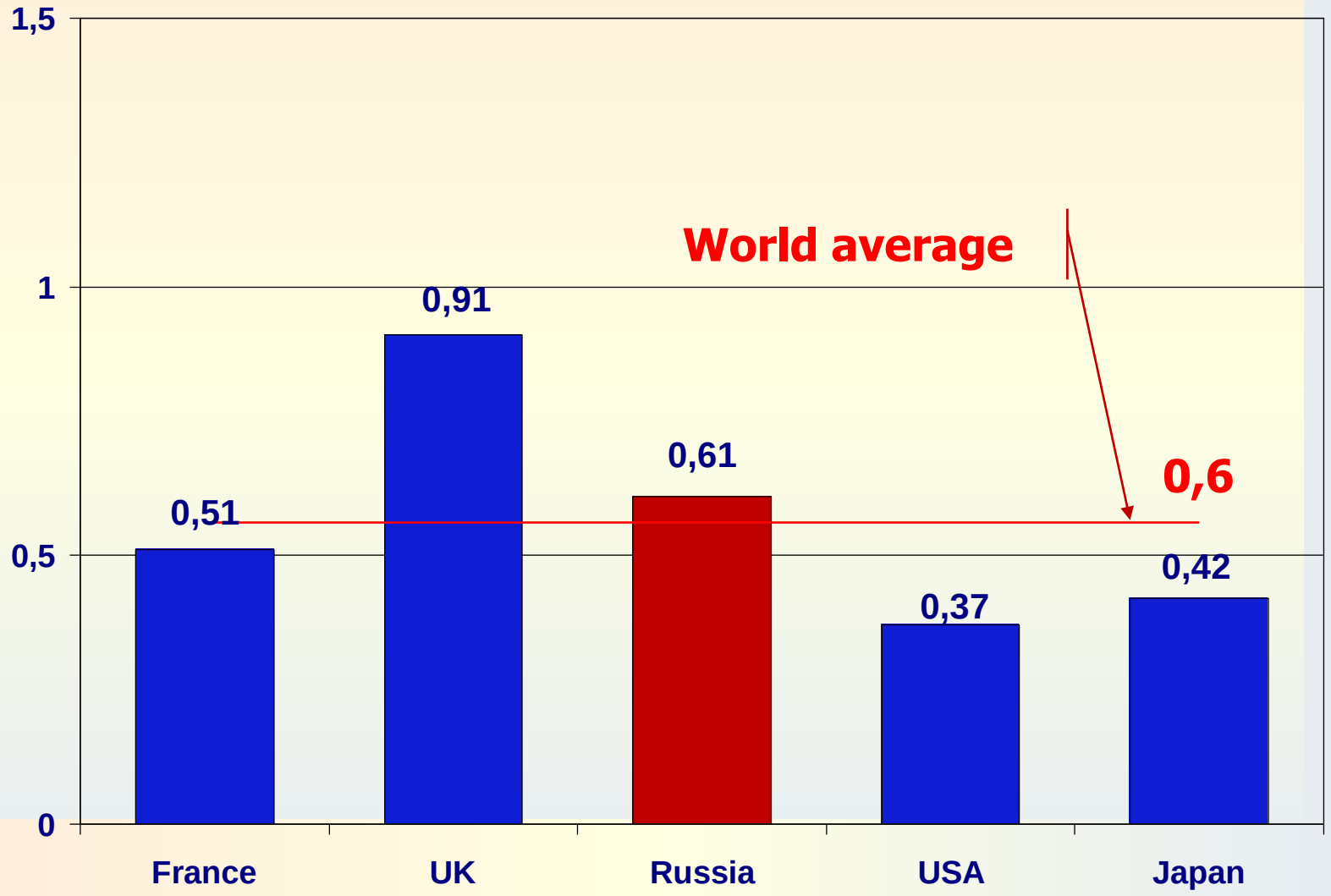
# Execution of the planned target for electricity generation at Russian NPPs in 2011 (% and mln. kW-h)



# History of NPP operating events reportable to the Regulator

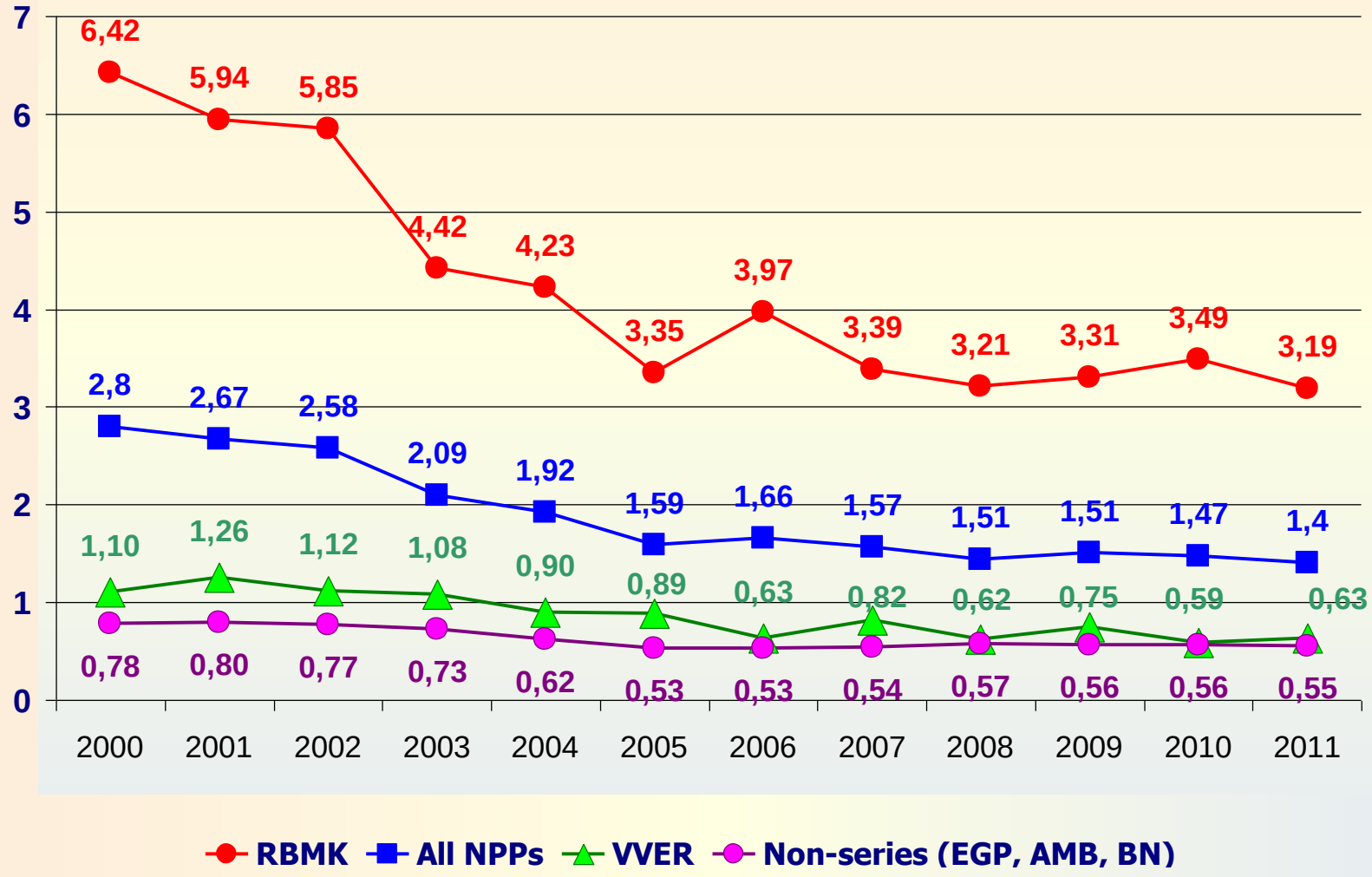


# Unplanned reactor scrams at NPPs of top 5 nuclear countries in 2011 (as per WANO method)

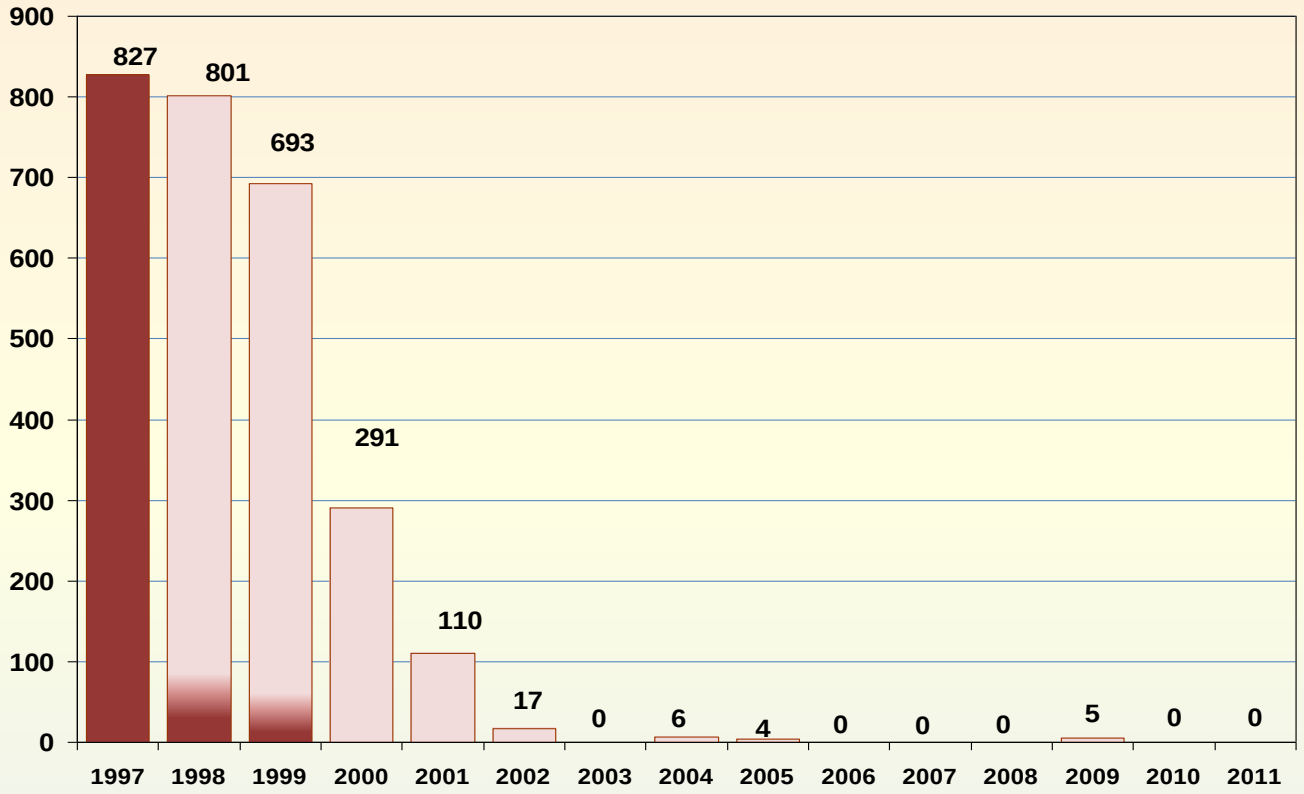


# Collective doses by reactor type

## (man-Sv/Unit)



# Number of personnel with doses exceeding 20 mSv
## (the limit set by RF law in 2000)




**NO incidents with radiological consequences**

# Summary of the year 2011

- Nuclear power units safe operation has been ensured
- The maximum electricity generation level of 172.7 bln kW-h (101.7% of the FTS balance target) has been achieved
- The maximum generation capacity of 25 GW has been attained

# Production targets for 2012

| | |
|---|---|
| **Planned generation as per FTS balance target** | **175.8 bln kW-h** |
| **Load Factor** | **80.8 %** |

# The main activity areas

- **Enhancement of safety and reliability of power units:**
  - **Elimination of safety deficiencies and non-conformancies;**
  - **Application of results of domestic and international nuclear OpEx analysis;**
  - **Introduction of new fuel types;**

# The main activity areas

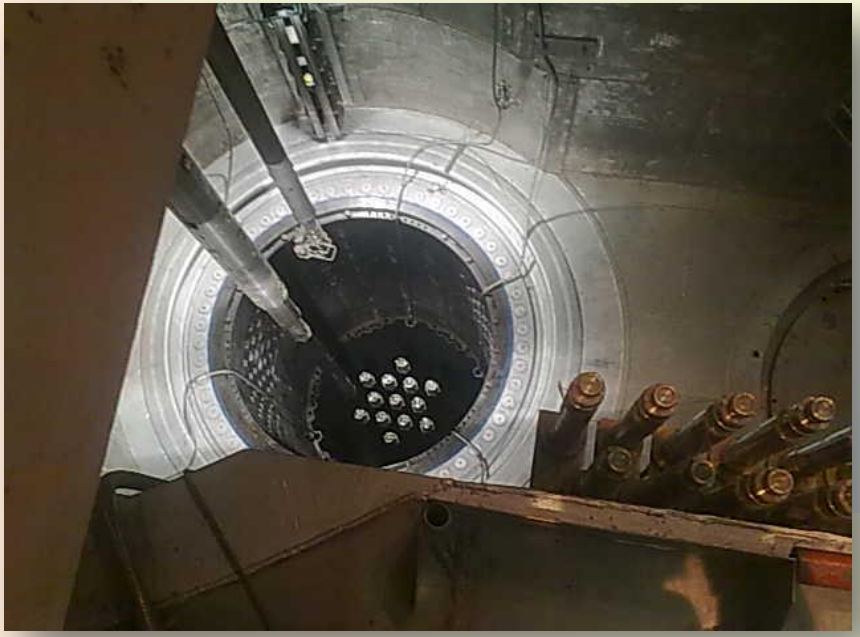
- **Increase of electricity generation efficiency :**
  - **Outage optimization;**
  - **Turbine unit efficiency factor increase;**
  - **Reactor unit uprate.**

# The main activity areas

- Power unit operating life extension
- Provision for new NPPs readiness to operation;
- Management structure improvement

# Kalinin NPP Unit 4 commissioning

- Reactor assemblage 23 – 31 October 2011
- First criticality 08 November 2011
- Turbine test run 15 – 17 November 2011
- Connection to the grid 22 November 2011



# Power unit operating life extension (OLE)

**As of 01.03.2012, the activities aimed at operating life extension have been accomplished for 17 nuclear power units with total installed capacity of 9802 MW:**

| NPP | Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 |
|---|---|---|---|---|---|
| Leningrad | RBMK-1000 | RBMK-1000 | RBMK-1000 | RBMK-1000 | |
| Kursk | RBMK-1000 | RBMK-1000 | | | |
| Bilibino | EGP-6 | EGP-6 | EGP-6 | EGP-6 | |
| Beloyarsk | | | BN-600 | | |
| Kola | VVER-440 | VVER-440 | VVER-440 | | |
| Novovoronezh | | | VVER-440 | VVER-440 | VVER-1000 |

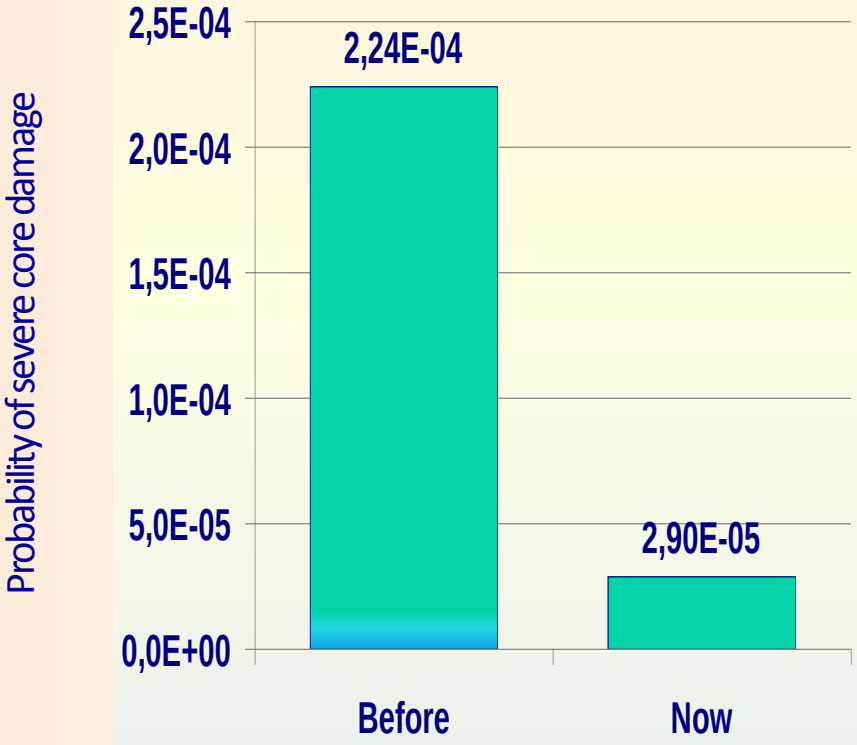
# Target-oriented modernization, a part of OLE activities

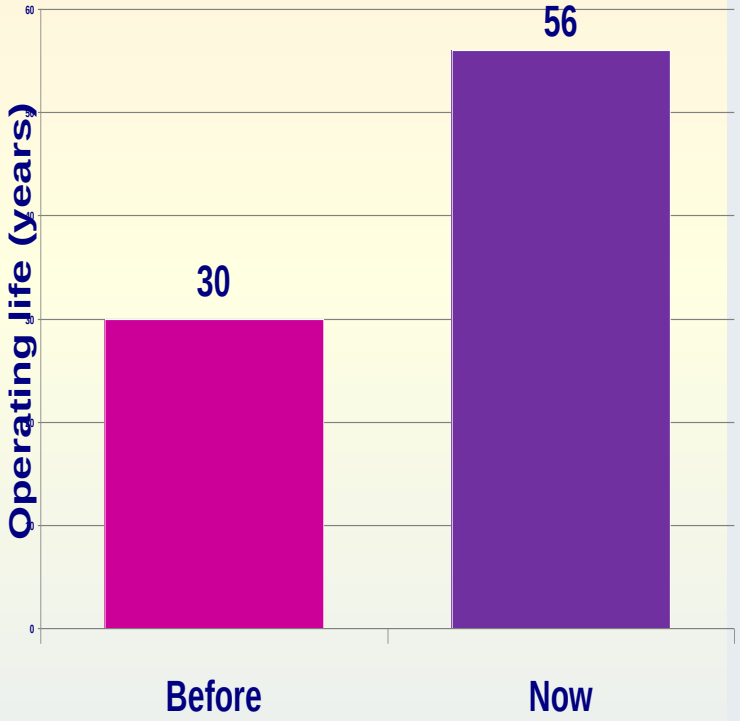
## Novovoronezh NPP Unit 5 (VVER-1000/V-179)

### (2008 – September 2011)

- Modernization of Emergency power supply system
- Implementation of two-set Reactor control & protection system
- Introduction of a supplementary system for emergency feedwater injection into steam generators
- Implementation of hydrogen explosion protection
- Implementation of gas-based fire extinguishing systems in the Unit control & protection premises
- Replacement of turbine generator excitation systems with digital ones
- Replacement of generator switches with $SF_6$-based ones
- Replacement of reactor upper unit and nut wrench of the main plug and socket device

# Novovoronezh NPP Unit 5 (VVER-1000/V-179) (2008 – September 2011)



# Target-oriented upgrading, a part of OLE activities

## Leningrad NPP Units 3, 4 (RBMK-1000)

- Upgrading of Reactor control & protection system with introduction of a second Reactor shutdown system
- Introduction of safety control systems
- Introduction of Emergency control room
  - Fuel channel replacement
  - Upgrading of safety systems (Emergency reactor cooldown system, Accident confinement system; Emergency power supply systems)
  - Implementation of acoustic system for reactor leak control

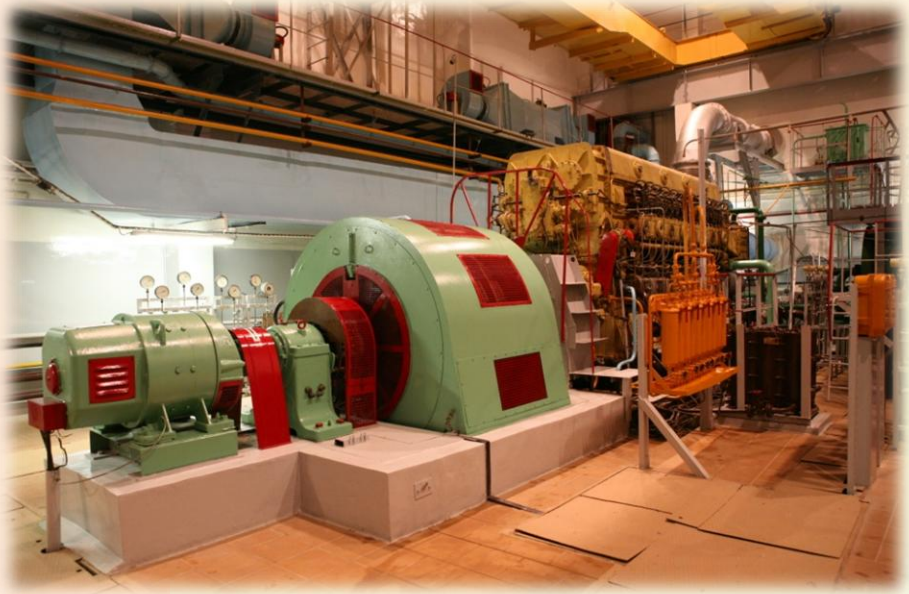
# Leningrad NPP Unit 4 upgrading (cont'd)

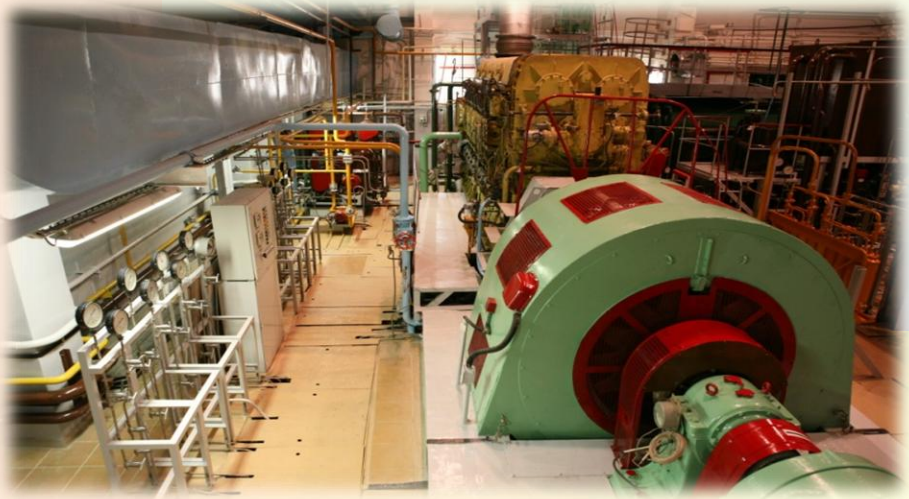
## Upgraded power supply system

## Unit 4 MCR upgraded

# Leningrad NPP Unit 4 upgrading (cont'd)

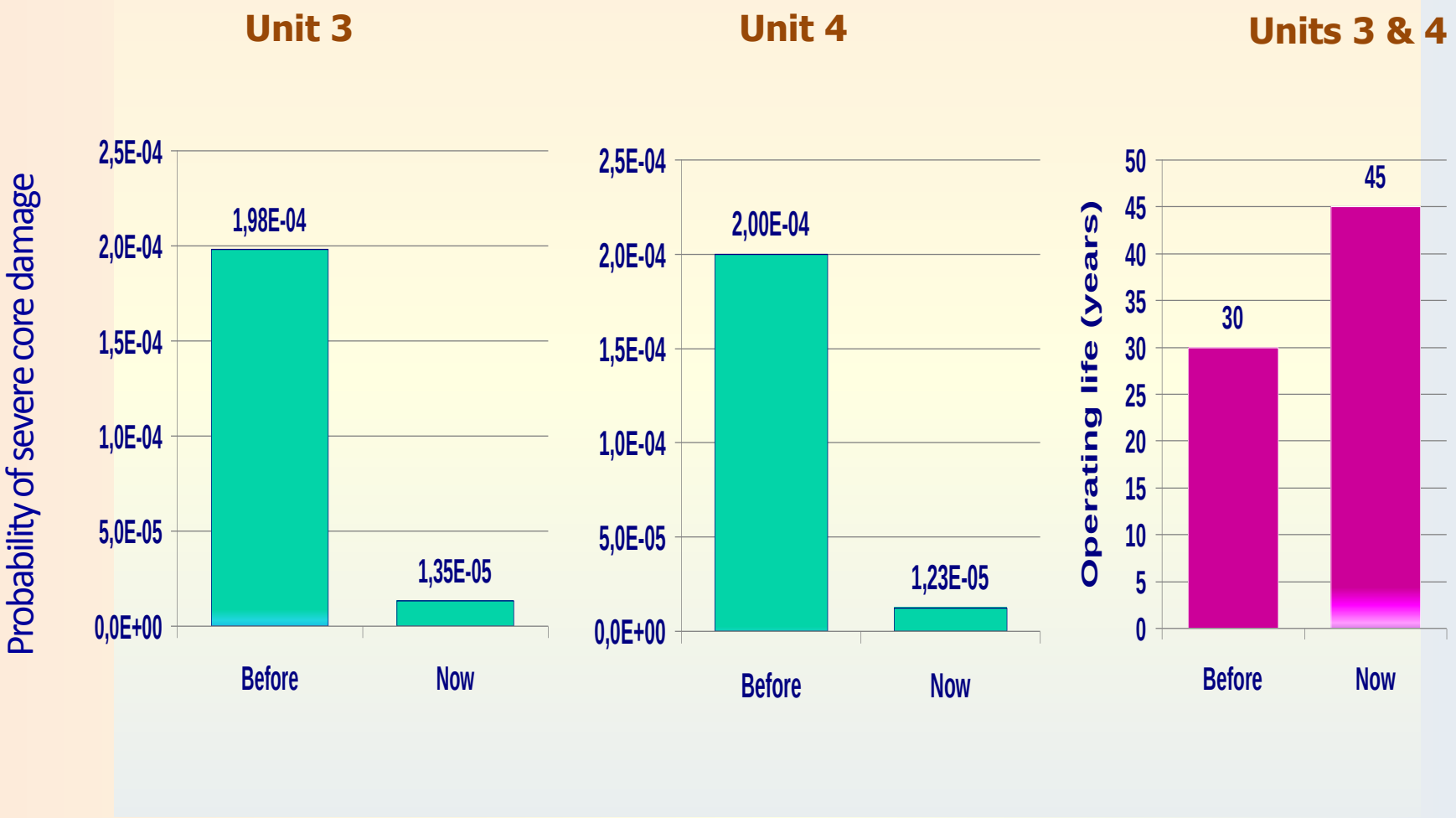
## Upgraded Diesel generator





## Batteries

# Leningrad NPP Units 3, 4 (RBMK-1000)



# Target-oriented upgrading, a part of OLE activities

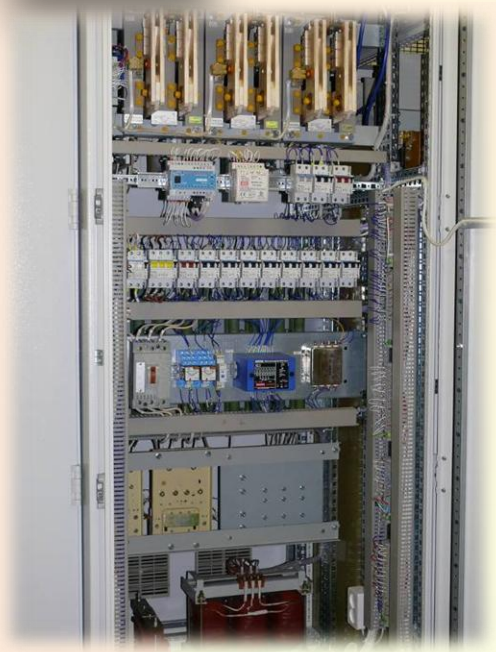
## Kola NPP Unit 3 (VVER-440/V-213)

- Upgrading of safety control systems and reactor control systems with introduction of a software & hardware complex (AREVA)
- Upgrading of Emergency power supply system: replacement of batteries, DC switchboards, DG stepwise loading automation
- Upgrading of Service water system for exclusion of any common cause failure (physical separation and pump redundancy)
- Implementation of hydrogen explosion safety system
- Implementation of gas-based fire extinguishing systems in the Unit control & protection premises
- Replacement of turbine generator excitation systems with digital ones

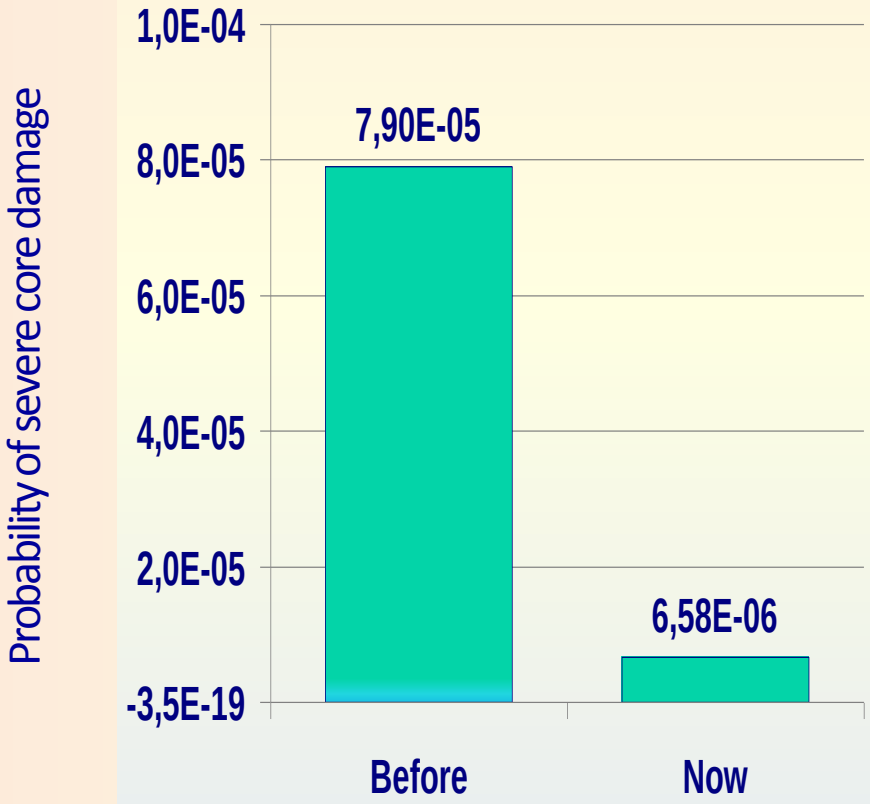
# Kola NPP Unit 3 - MCR

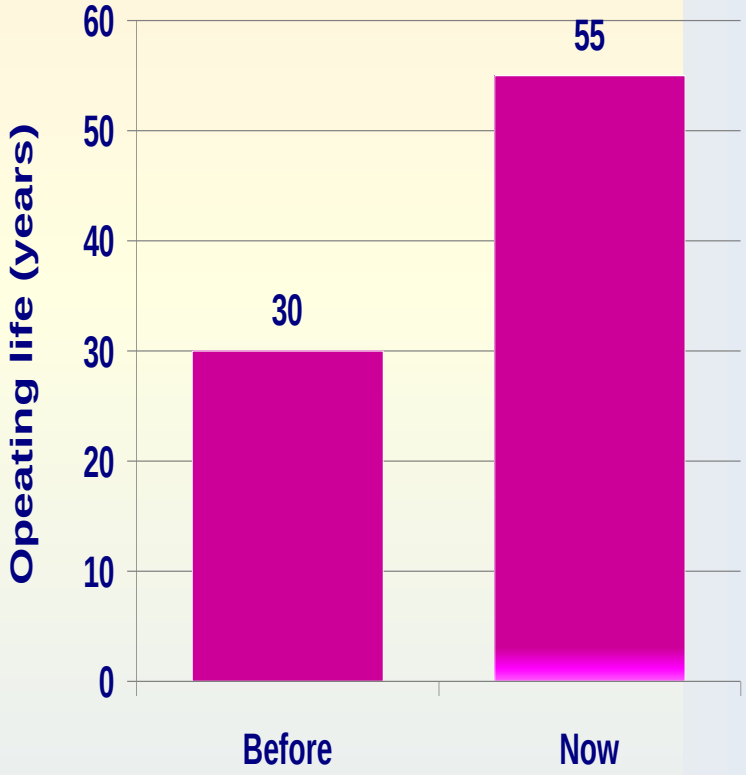


# Kola NPP Unit 3 – New TG excitation system



# Kola NPP Unit 3 (VVER-440/V-213)



# Target-oriented upgrading, a part of OLE activities

## Beloyarsk NPP Unit 3 (BN-600)

- Implementation of reactor control & protection systems with introduction of a second emergency shutdown equipment set
- Introduction of Emergency control room
- Replacement of Steam generator modules
- Upgrading of DC switchboards, current transducer cabinets, Emergency power supply system
- Upgrading of switchgears of the in-house power supply system
- Updating of radiation monitoring system

# Safety-improving activities implemented at Beloyarsk NPP Unit 3

## Second Emergency protection set and redundant Emergency control room

2nd set for emergency shutdown by neutronics and process parameters

Redundant Emergency control room

# Safety-improving activities implemented at Beloyarsk NPP Unit 3 (cont'd)

## 3nd train of EPSS-1

**Cabinets of current transducers – rectifier and inverter**


**DC switchboard SchPT-3D**



**Switchgear 0.4 kV 6NN-1**

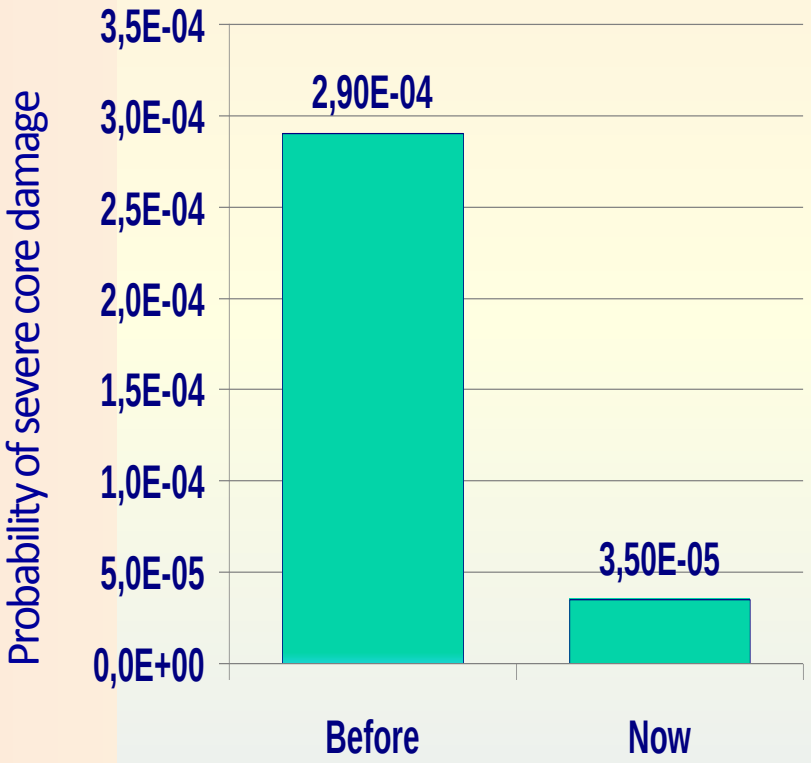
# Safety-improving activities implemented at Beloyarsk NPP Unit 3 (cont'd)

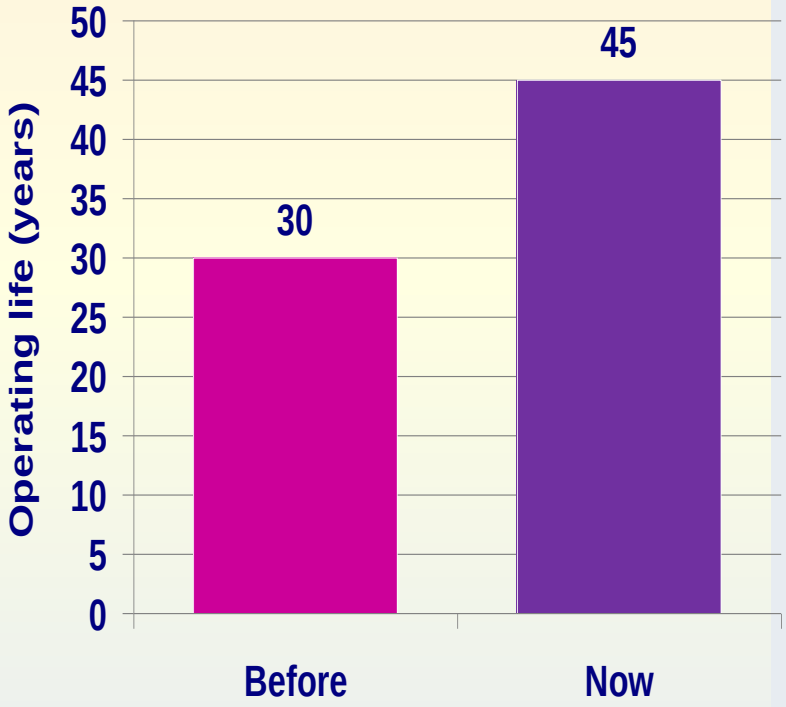
Radiometer RZBA "Positron" for contaminated surfaces

## Upgraded Radiation monitoring system

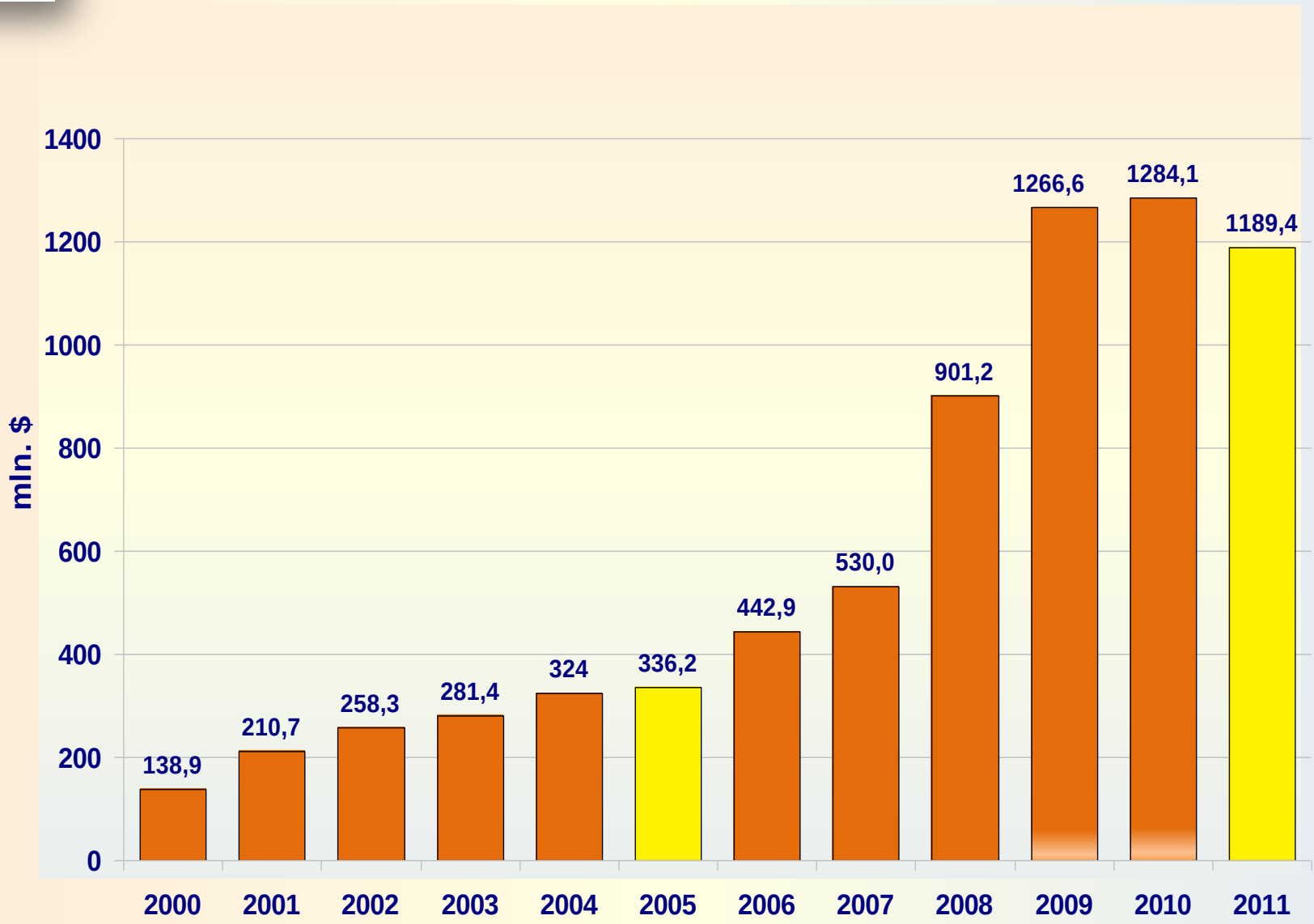
Dosimetric monitoring panel

# Beloyarsk NPP Unit 3 (BN-600)



# NPP upgrading costs



# Prospects of VVER fuel development

- Further increase of uranium-235 content in VVER fuel due to fuel enrichment raising over 5% (up to 7%) on the base of 7.6/1.2 mm fuel pellets.
- Further enhancement of fuel cycles:

➥ improving performances in 18-month fuel cycle;

➥ development of mixed fuel cycles;

➥ justification of erbium as a burnable absorber.

# JSC "Concern Rosenergoatom" advanced goals regarding the use of MOX fuel in BN and VVER-TOI reactors

- Faster establishment of closed fuel cycle aimed at fuel utilization efficiency improvement by means of uranium-235 replacement with plutonium based on breeding of the latter in fast neutron reactors .

  JSC "Concern Rosenergoatom" acknowledges this goal as a priority in the development strategy.

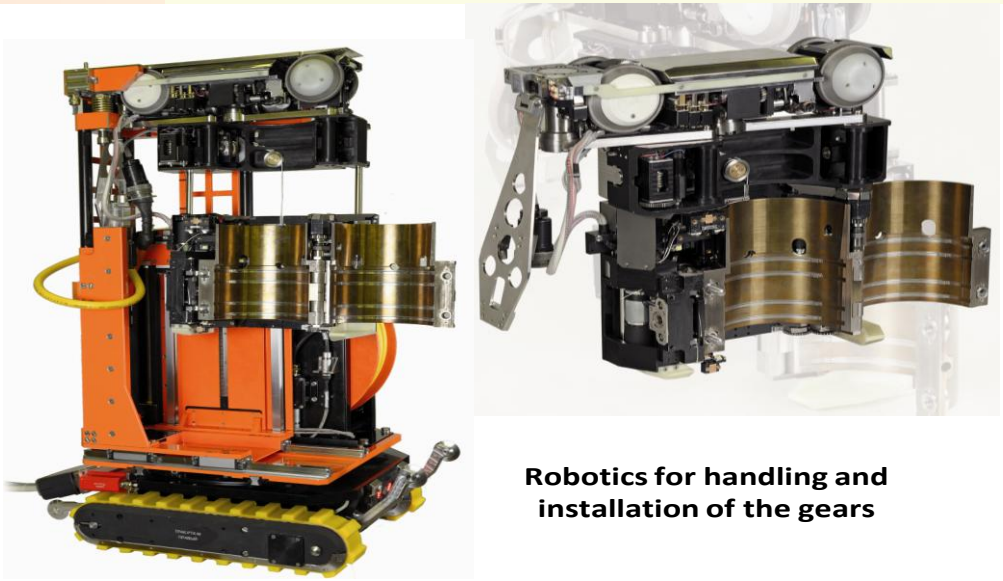
- It is planned to:
  - Perform tests to justify MOX fuel use: 2016;
  - Design and establish a single manufacture for MOX fuel pellets production for VVER-TOI and BN reactors: 2012 to 2018.

# Implementation of robotics to solve operational tasks

- **An alternative technology for recovery of extension pipe joints (TSTs) of metal structure with graphite stack has been developed and implemented at Leningrad NPP Unit 1.**

**The following benefits are achieved :**

- **reduction of specific cost of one TST cell recovery by factor of 3 (as compared to the conventional method);**
- **elimination of high-level SRW generation;**
- **reduction of dose loads on personnel by factor of 200;**
- **three times more efficient TST recovery**



Robotics for handling and installation of the gears

# SNF management

**In accordance with the "Programme for infrastructure establishment and management of SNF for 2011-2020 and period till 2030" it is planned to:**

- **accomplish construction of the SFA disassembling complex and start SNF dispatching to the FSUE "GKhK":**
  - **at Leningrad NPP – in 2012,**
  - **at Kursk NPP – in 2013,**
  - **at Smolensk NPP – in 2015;**
- **Start dispatching of ill-conditioned RBMK SFAs to the FSUE "Mayak" for reprocessing in 2013.**

# RBMK SFAs: disassembling works and dispatching to FSUE "GKhK"

**In December 2011, the startup load test phase has been initiated at Leningrad NPP, with SFA disassembling that yields fuel bundles to be placed into transport containers of TUK-109 type.**

**48 TUK-109 containers are ready for SNF loading.**

# RBMK SNF removal from NPP site

- In March 2012, a first pilot train departed from Leningrad for FSUE "GKhK", which comprises two TUK-109 containers loaded with RBMK SNF. The second train container loading works are under way.
- In total for 2012, it is planned to dispatch three trains with 8 transport containers each

# Post-Fukushima reviews and analyses of NPP safety

- **In-depth safety analysis has been carried out using modern calculation codes, and safety justification cases have been re-issued for:**
  - **all nuclear power units with 1st Generation RBMK-1000 and VVER reactors currently in operation**
  - **all nuclear power units of Bilibino NPP**
  - **power unit 3 of Beloyarsk NPP**
- **In-depth safety analysis activities are going on for 2nd and 3rd Generation VVER and RBMK reactors**

# Organization of NPP resistance analysis jointly with Rostechnadzor:

JSC Concern Rosenergoatom

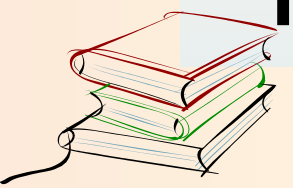
- General Designer
- Reactor Unit designer
- Scientific Leader

**Analysis of safety ensuring has been performed for every credible external impact**

Balakovo | Beloyarsk | Bilibino | Kalinin | Kola | Kursk | Leningrad | Novo-voronezh | Rostov | Smolensk

Russian NPPs

**The "Reports on NPPs Safety Analyses with regard to Extreme External Impacts"**



# Results of the resistance assessments for NPPs

**1**

Modernization works aimed at NPPs safety improvement have been accomplished during last 10 – 15 years

**2**

Vulnerabilities have been identified and hypothetic initial event lists have been compiled for each NPP

**3**

Implementation of supplementary measures focused on NPP robustness enhancement is needed

**4**

Not all BDBA initial events were considered in designs of the operating NPPs

- Total loss of options of heat removal from the reactor unit
- Complete and durable (over 10 days) loss of NPP connections to external power sources
- Combination of 2 or more failures that are independent of the initial event

# Significant events
# Comprehensive emergency response exercise (KPU) at Novovoronezh NPP with OPAS group involvement 9-11 November

## The following organizations took part in the KPU

- OPAS group
- Novovoronezh NPP
- Representatives of 7 international organizations and states
- Rosatom
- NF ETC S.Petersburg
- Local authorities of Voronezh Region and Novovoronezh town
- Rostechnadzor
- Emercom of Russia
- Insurance companies

**In course of the exercise, preparedness to actions in case of extreme impacts on the NPP leading to loss of in-house power supply and loss of cooling water supply has been successfully verified, with "stress test" results and Fukushima-1 lessons learned taken into account.**

# WANO Peer Review findings

- Equipment and resources available for JSC “Concern Rosenergoatom” provide for a sound support to emergency response actions;

- In the wake of Fukushima accident there have been undertaken aggressive actions in the area of emergency preparedness and exercises with the goal of ensuring JSC “Concern Rosenergoatom” preparedness to act under conditions of a beyond-design-basis accident.

# OSART missions in Russia

**By request of the RF Government, IAEA international experts performed OSART missions to review operational safety of Russian NPPs :**

**2005**
**Rostov NPP**

**2014**
**Kola NPP** *(planned)*

**2008**
**Balakovo NPP**

**2011**
**Smolensk NPP**

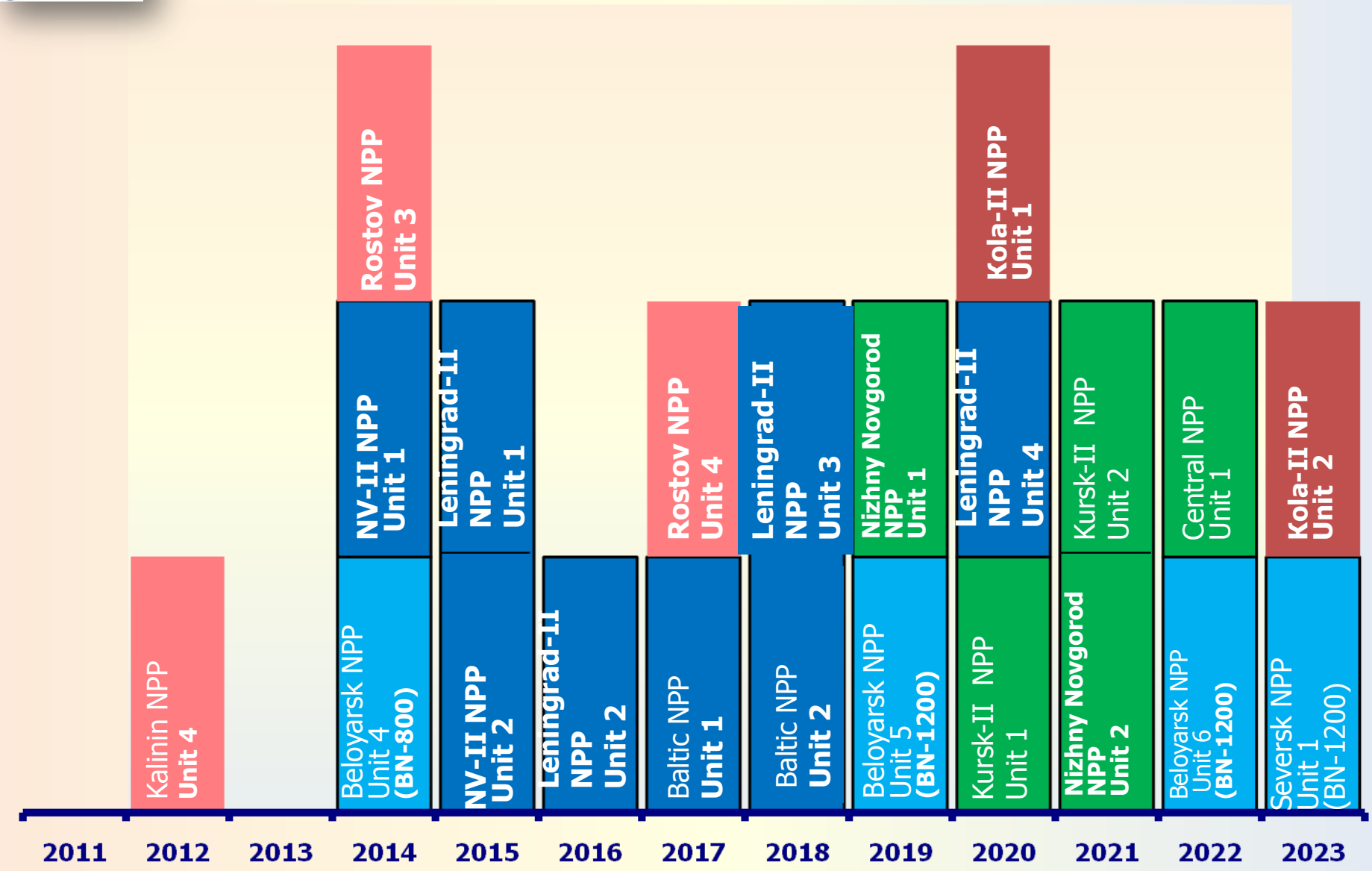
# OSART mission at Smolensk NPP. Basic findings

| | Review area | Recommendations | Suggestions | Good Practices |
|---|---|---|---|---|
| 1 | Management, Organization & Administration | | 2 | |
| 2 | Training & Qualification | | | 1 |
| 3 | Operation | | 3 | 1 |
| 4 | Maintenance | 1 | 1 | 2 |
| 5 | Technical support | 1 | 1 | 1 |
| 6 | Operating experience feedback | | 1 | 2 |
| 7 | Radiation protection | | 2 | 2 |
| 8 | Chemistry | | | 1 |
| | Total: | 2 | 10 | 10 |

# NPPs under construction: current status

- **Completion of VVER-1000 power units construction:**
  - Rostov NPP, power units 3, 4
  - Kalinin NPP, power unit 4 (power test operations)
- **Construction of power units of AES-2006 design:**
  - Novovoronezh-II NPP, power units 1 & 2
  - Leningrad-II NPP, power units 1 & 2
- **Construction of power unit with BN-800 reactor:**
  - Beloyarsk NPP, power unit 4
- **Construction of floating co-generation power plant with KLT-40 reactor** (Vilyuchinsk)

# Russian nuclear power roadmap



# Construction of new power units
## Beloyarsk NPP Unit 4

# Construction of new power units
## Novovoronezh-II NPP

# Construction of new power units
## Leningrad-II NPP

# Construction of new power units
## Rostov NPP Units 3 and 4

# Construction of new power units
## Baltic NPP

# VVER-TOI NPP

## Protection from external impacts

### TORNADO, HURRICANE

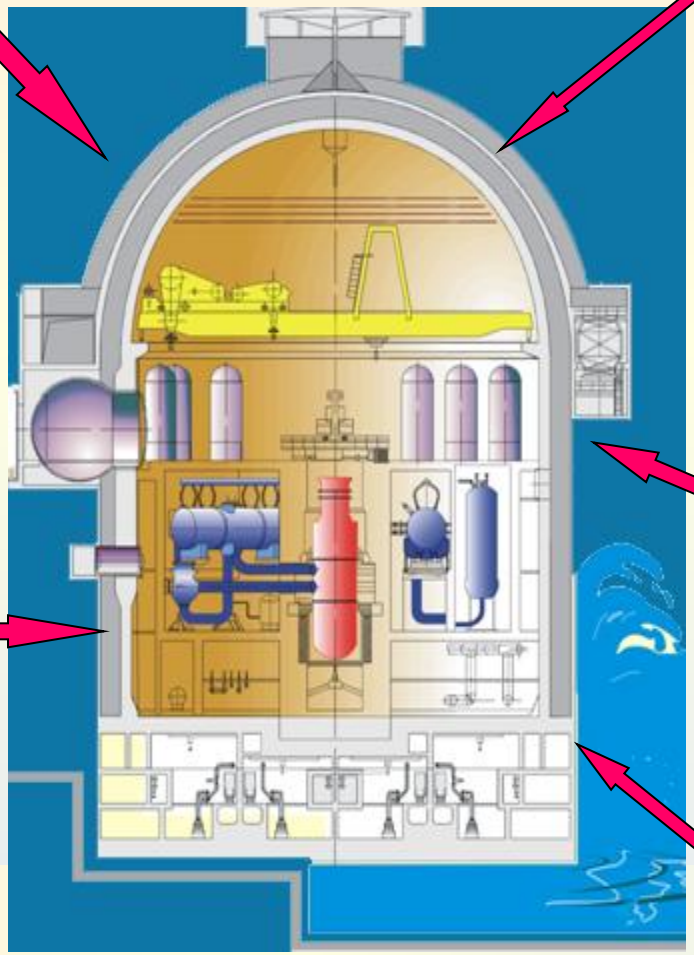
Maximum design wind velocity of 56 m/s (tearing off roofs, uprooting big trees, overthrowing railway carriages, blowing out cars off-road )

### SHOCK WAVE

With frontal pressure of 30 kPa

### SEISMIC IMPACTS

Basic impact:
MDE – 7 point as per MSK-64 scale
DE – 6 points
Option:
MDE – 9 point as per MSK-64 scale
DE – 8 points



### AIRPLANE CRASH

Basic impact:
20.0 tons with 200 m/s velocity
Option: 400.0 tons

### FLOODS, STORMS

As applicable to specific site conditions

### PROLONGED LOSS OF POWER AND WATER SUPPLY

# Conclusion

- ✓ Safe operation of Russian nuclear power units is ensured by JSC “Concern Rosenergoatom” management and personnel
- ✓ JSC “Concern Rosenergoatom” demonstrates its ability to respond in adequate, prompt and efficient manner to new challenges in the field of NPP operational safety
- ✓ The system for ensuring safety of Russian NPPs, which is based on the Defense-In-Depth concept , is not subject to any revision and constitutes the bases of technical policy of the operating organization, JSC “Concern Rosenergoatom”
- ✓ JSC “Concern Rosenergoatom” fully discharges the roles and responsibilities of the operating organization as stipulated by the laws of the Russian Federation in the field of the use of atomic energy