The IAEA future roles in support of technology and innovation: perspective of a ‘mature’ country

Vladimir Asmolov

Deputy Director General – Director for Science & Engineering, Energoatom, Russia

IAEA, Vienna, September 2008

The revival of nuclear power - implementation of objective capabilities of nuclear power

Nuclear power "renaissance" - External boundary conditions:

- irregularity in the distribution of global organic fuel resources
- growth of consumption in the world energy market

Government and public – global expectations:

Expansion of nuclear power application to meet basic human needs

Nuclear power "renaissance" – Internal boundary conditions (proposed consumer properties):

- guaranteed safety (as safe as possible)
- cost-effectiveness (as efficient as possible)
- closing of nuclear fuel cycle:
  - spent fuel and radioactive waste management
  - fuel breeding

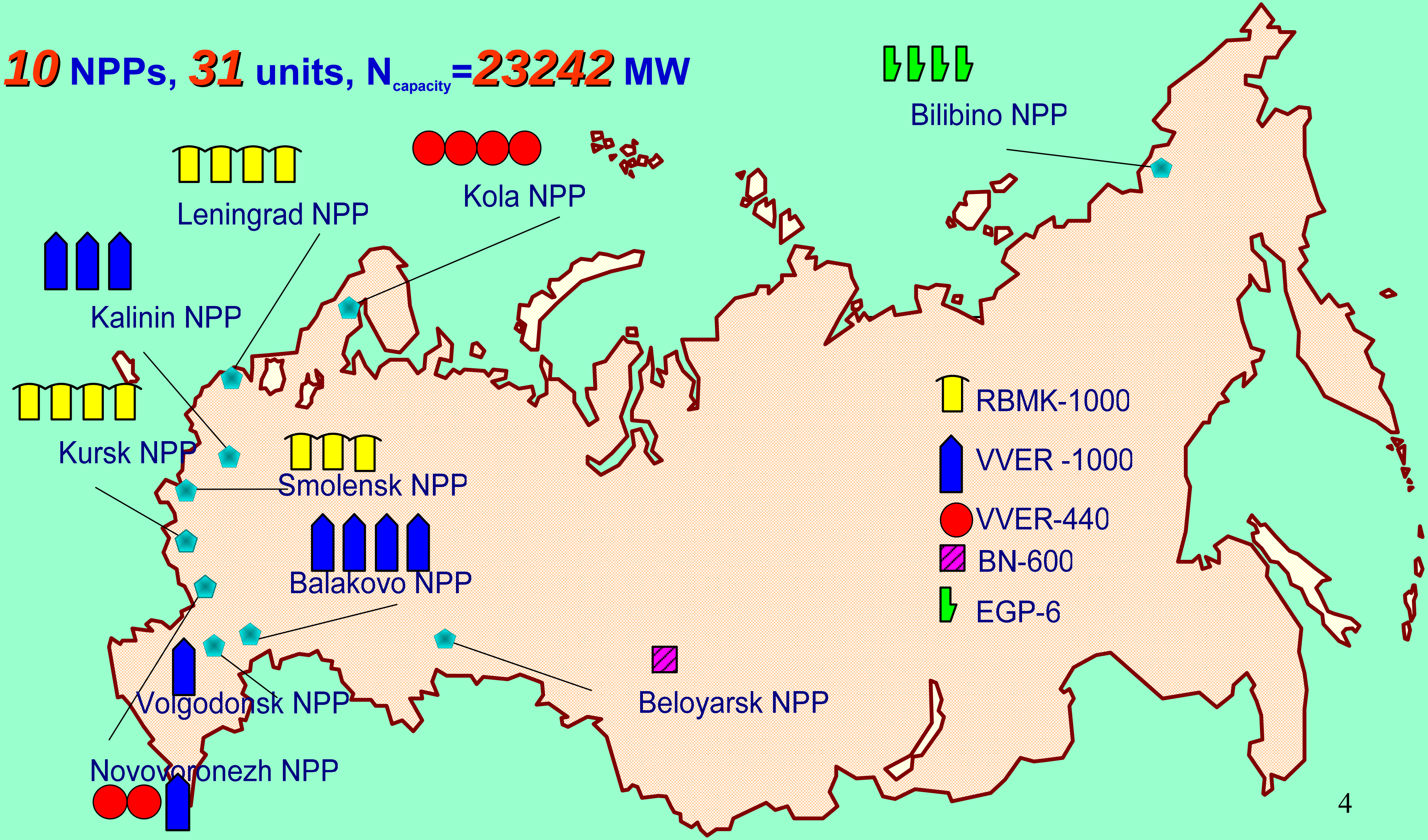
Available nuclear technologies for different purposes

Technology	*Purpose*
Water cooled thermal reactors	1. Electricity generation and expansion of installed capacities 2. Combined generation of electricity and heat 3. Regional nuclear power supply
High temperature reactors	1. High-grade heat 2. New energy carriers
Fast reactors	Transition to the qualitatively new level: – in fuel employment – in radioactive waste and spent fuel management

Nuclear power of Russia at the beginning of XXI century

2007 – 158.7 Bln kWh

10 NPPs, 31 units, $N_{capacity}$=23242 MW



Russian program - priority tasks
Operational NPP

Objectives	Contents of works
<u>Program of operational NPPs upgrading for 2007 – 2012</u> **Efficiency improvement for operational NPPs with VVER and RBMK reactors**	• ***Activities aimed at the increase of power, capacity factor, fuel burnup, manoeuvring capabilities;*** • ***Justification of the life-time extension based on the in-depth safety analysis***

The program implementation is equivalent to the commissioning of 4 power units of NPP-2006 by 2012

Russian program - priority tasks
VVER technology

Objectives	Contents of works
<u>Federal program</u> **Increase of investment effectiveness:** ■ **Efficiency increase;** ■ **Improvement of fuel cycles;** ■ **Increase of unit power;** ■ **Reduction of construction terms;** ■ **Reduction of material consumption**	● ***Development and implementation of the NPP-2006 /1200 design;*** ● ***Development of NPP designs with reactors of low and average power for regional energy supply***

The Russian Federal program - objective characteristics based on NPP-2006 commissioning

Characteristic	2006	2010	2015	2020
NPP installed capacity, *GW*	***23.2***	***24.2***	***33.0***	***41.0***
Electricity generation, *TW•hour/year*	***154.7***	***170.3***	***224.0***	***300.0***
Nuclear electricity fraction in the total scope of electricity generation in Russia, *%*	***16.0***	***16.0***	***18.6***	***20-23***
Reduction of operating costs (by the level of 2006), *%*	***100***	***90***	***80***	***70***
Reduction of per unit investments, *%*	***100***	***90***	***85***	***70***

Guaranteed Safety

NPP
2006

Economic advisability

Achieved goals of the NPP-2006 design

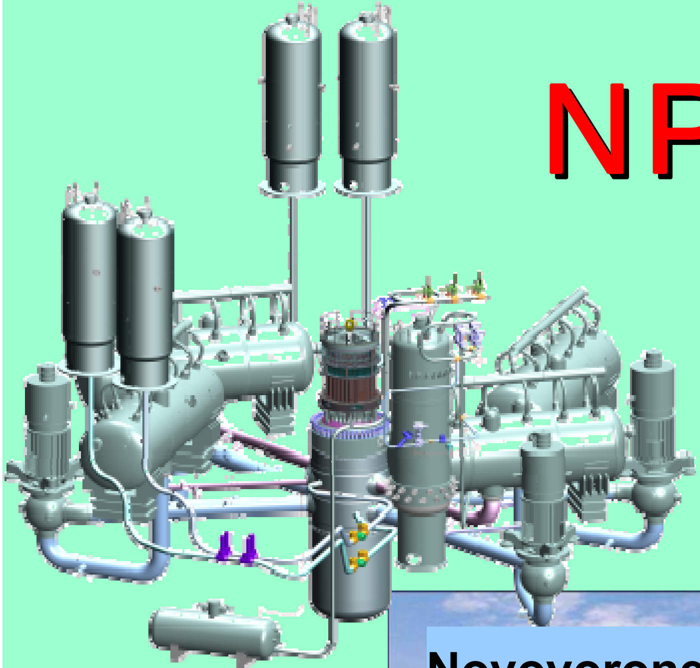
- **Thermal power was increased up to 3200 MW(th) and the power unit (gross) efficiency was raised up to 36.2% due to:**

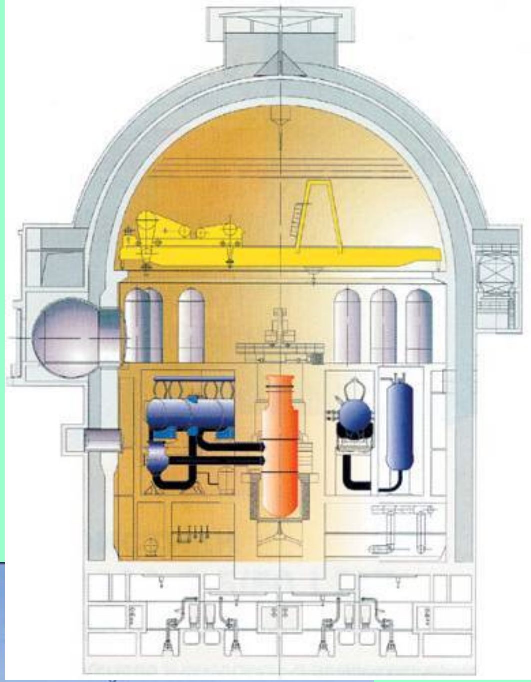
  - elimination of excessive conservatism;
  - improvement of the steam-turbine unit flow diagram;
  - increase of steam pressure parameters at the SG outlet ;
  - reduction of pressure losses in steam lines.

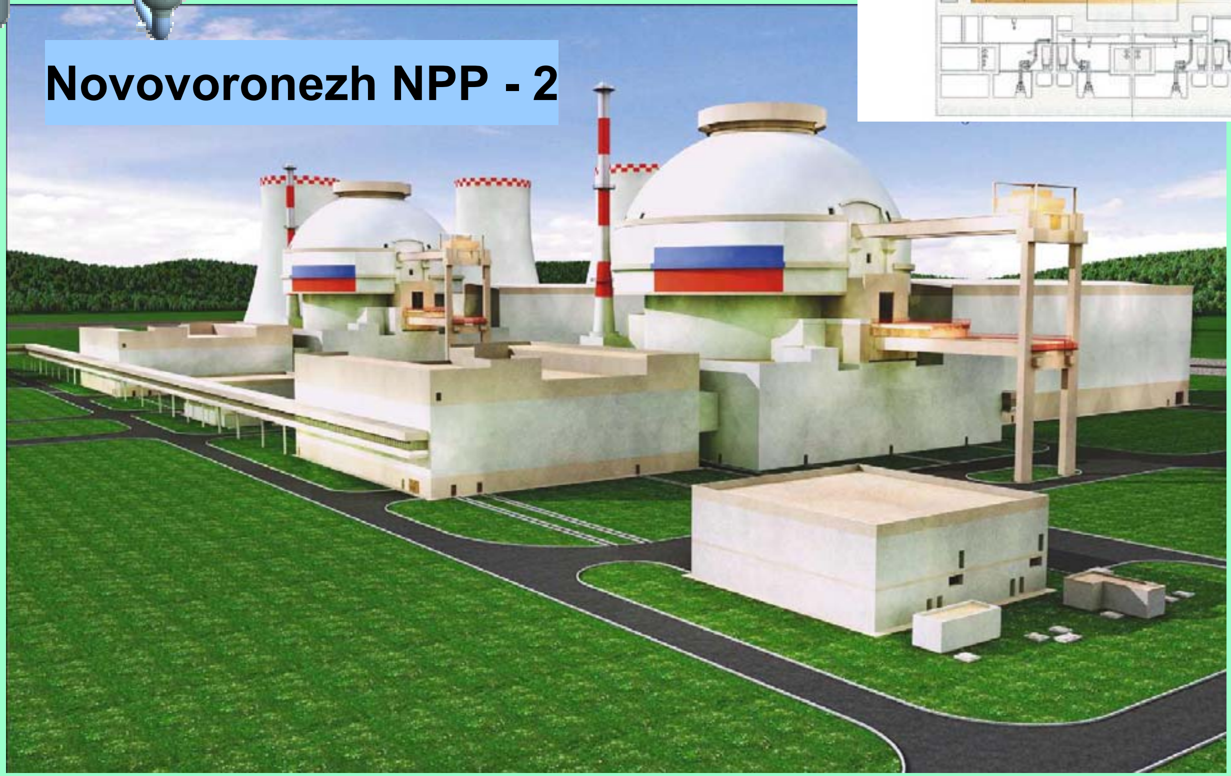
- **Economic efficiency was improved due to:**

  - optimization of passive and active safety systems;
  - unification of the equipment used;
  - diminishing of material consumption;
  - shortening of the construction period.

NPP-2006



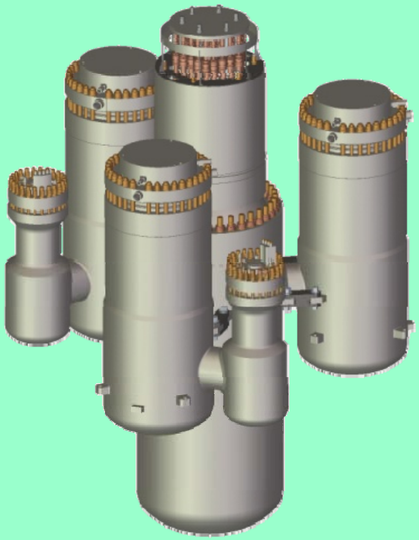




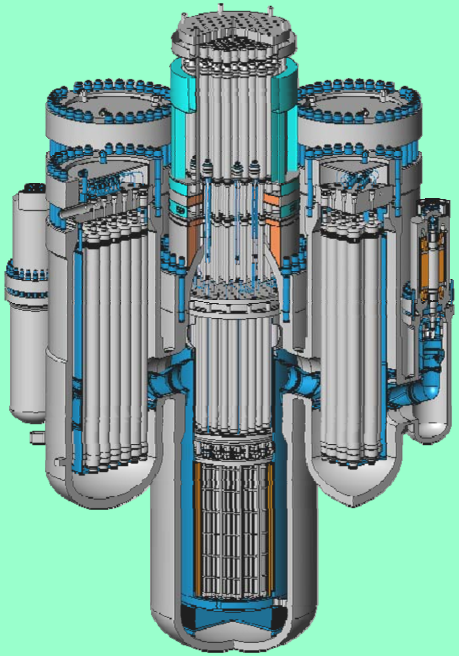
Reactors for regional energy supply

VBER design power range

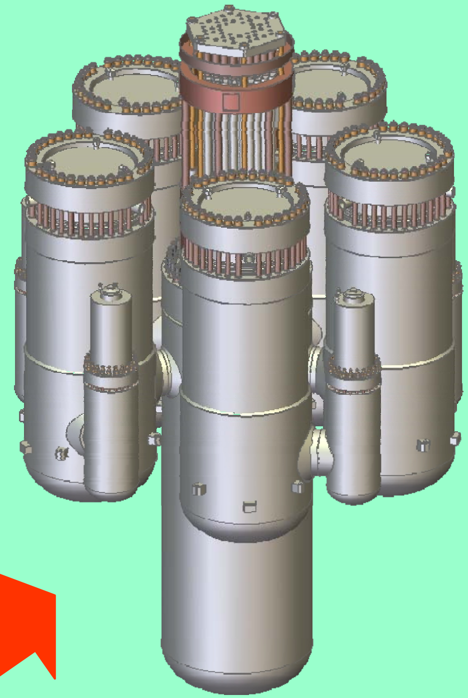
N=694 MW
(250 MWe)
N=547 MW
(200 MWe)
N=407 MW
(150 MWe)
N=271 MW
(100 MWe)



N=930 MW
(335 MWe)
N=830 MW
(295 MWe)



N=1167 MW
(420 MWe)



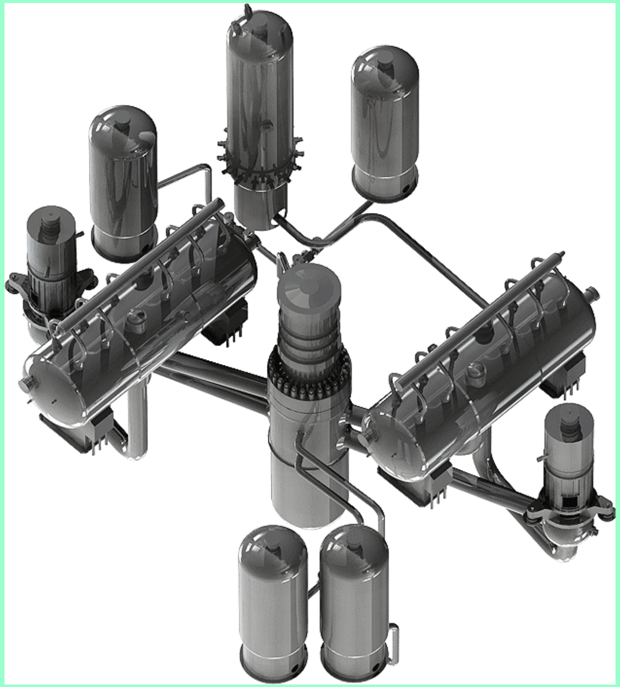
The VBER technology allows to create power units in the power range from 100 to 420 MWe based on the unified solutions

Conceptual approach to the NPP-2006/600 design

NPP-2006/1200

VVER-640 NPP

VVER-600



Floating NP with reactor unit of KLT-40S type

LENGTH, m	140.0
WIDTH, m	30.0
BOARD HEIGHT, m	10.0
IMMERSION, m	5.6
DISPLACEMENT TONNAGE, t	21 000

INSTALLED CAPACITY	
• ELECTRIC, MW	70 / 38
• THERMAL, Gcal/h	50 / 146.8
COST, billion rubles	9 – 10
CONSTRUCTION TERM	4 years
PRODUCTION OUTPUT	
• ELECTRICITY, mln.kW-h/year	455
• THERMAL ENERGY, thous.Gcal/year	900

System problems of modern nuclear power

- **Low utilization efficiency of the mined natural uranium – less than 1%**
- **Permanently growing volumes of SNF and RW**

General requirements to the future Nuclear Power System (NPS)

- Economical efficiency
- Guaranteed safety
- No limitations in regard to a raw material resources **for a historically significant time span**
- SNF and RW management **– the NP fuel cycle shall be organized in a way that ensures safe ultimate isolation of RW**
- Power generation scale **– the share at national electricity market should be not less than 30%**
- Energy generation structure **shall ensure an opportunity to expand market sales (heat, new energy carriers, desalination)**

Russian program - priority tasks
Fast reactors

Objectives	Contents of works

New technological platform
 	
Preparation for the implementation of the concept of closing the fuel cycle in uranium and plutonium
	• Development of requirements on fast reactors (fuel breeding, time for the outer fuel cycle in plutonium, safety, economics, staging, implementation terms);
	• Development of the commercial NPP with fast sodium reactor;
	• Development of technical proposals
	  ▪ On nuclear fuel cycle pressing problems and technologies;
	  ▪ On spent fuel management;
	  ▪ On fast gas-cooled reactors;
	  ▪ On fast reactors with heavy metal coolant

Analysis of the current status fast reactor development with different coolants

1. Fast reactors with sodium coolant	***Operability and safety were demonstrated***
2. Fast reactors with heavy metal coolants	***There is a basis for the continuation of development to obtain a practical evidence of efficiency in the head-end (lead – bismuth) and test (lead) facilities***
3. Fast gas- and steam-cooled reactors	***At the level of concept studies***

Development of a closed nuclear fuel cycle technology for the near-term prospect up to 2020

Russian new technology platform program

Construction and start-up of the pilot BN-800 reactor with mixed U-Pu fuel

Establishing of a pilot production of mixed fuel and fabrication of the first loading for BN-800

- pellet fuel,
- vibration compacted fuel ?

Commercial NPP with sodium breeder
development of a detailed design construction

- pattern, characteristics,
- power rank ?

Construction of industrial mixed fuel production and a fuel regenerating plant
R&D work, detailed design construction

of which fuel ?
method of fuel regeneration?

Reactors with heavy metal, gas coolant (SVBR, BREST) or others
R&D work, decision on implementation

to prove the theorem of existence ?

2005 2010 2015 2020

Russian program – long-term priority tasks

VVER technology

Objectives	Contents of works
Further development of the VVER technology	Development and implementation of technical requirements on the VVER innovation design (super VVER) with fundamentally new characteristics in: ➢ economics ➢ operational characteristics ➢ safety ensuring ➢ fuel breeding

Requirements to VVER technology development for its use in combination with the breeders within the closed NFC:

- Fuel utilization (breeding ratio) (Fast neutron spectrum)
- Efficiency coefficient (supercriticality)
- Investment payback time (large modules prefabrication, new construction methods)

Determination of conceptual design scope for the Super VVER technology development

- **A light-water vessel-type reactor in a NP system with closed fuel cycle with breading ratio ~ 0,9**

- **Power range:**
  600 – 1200 – 1600 ?

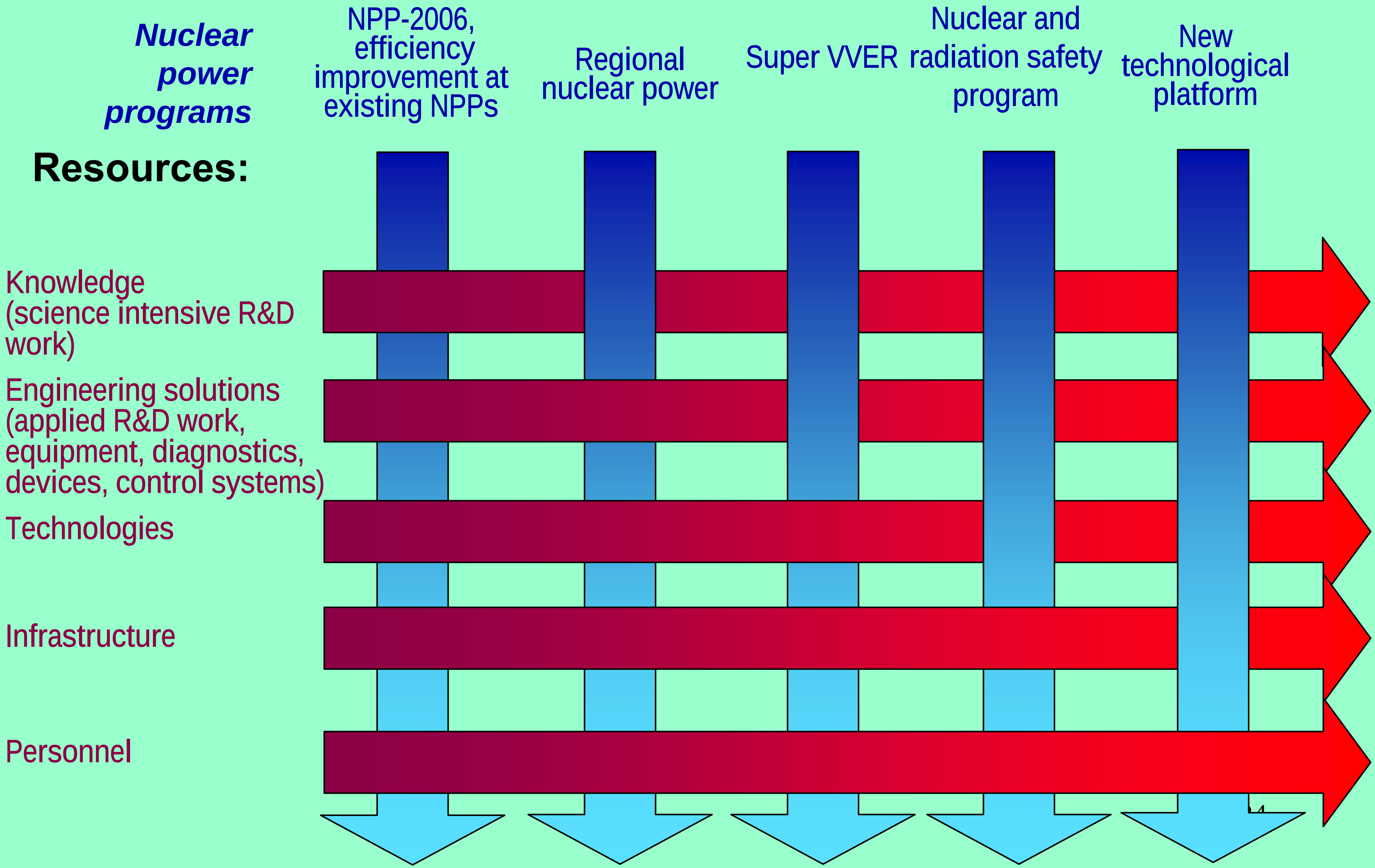
- **Coolant:**
  pressurized water? Supercritical pressure? Boiling? Moist steam?

- **The core:**
  - fuel – oxide, carbide, metal - to be chosen
  - fuel assembly dimensions – to be changed
  - fuel element diameter – to be changed
  - use of plutonium – yes
  - use of advanced cladding materials – yes

Optional look to the future of Russian nuclear power systems

Today		Mid of XXI century
NPPs with VVER-440, NPPs with VVER-1000 NPPs with RBMK	Basic electricity supply →	NPP-2006, NPP-2006M VVER-1000 NPPs
	electricity supply, additional fuel breeding →	NPP with SuperVVER for operation in the closed NFC with breeding ratio ~ 0,9
NPP with BN-600	electricity supply + fuel breeding →	NPP with BN-800 NPP with «commercial» breeders
Bilibino NHPP	District heating + electricity →	Regional nuclear plants with medium-size reactors
	High-potential heat, new energy carriers →	NP with High-temperature gas reactors
Open nuclear fuel cycle	→	Closed nuclear fuel cycle

Matrix of key programs and their resource provision



The IAEA have to facilitate the efficient and safe use of nuclear power

For "mature" countries

1. Further dissemination of experience with:
   - operation technologies;
   - management efficiency;
   - quality assurance;
   - knowledge management;
   - life time extension

2. The enhancement of the role to coordinate the international response to emergencies in accordance with signed conventions

For newcomers

The assistance in:

1. The establishing of:
   - necessary infrastructure;
   - authoritative guidelines

2. The disseminating
   - experience;
   - knowledge;
   - best practices

3. The providing
   - training;
   - peer reviews

The IAEA have to intensified attention on innovative activities

1. To coordinate expectations about technological developments across the full range of proposed designs (INPRO, TWG)

   - water cooled reactors

   - metal cooled reactors

   - gas cooled reactors

2. To provide priority to the improvement of important safety and economic characteristics

   - safety and security synergies

   - proliferation resistance

   - nuclear generation efficiency

   - construction time reduction

   - simplification

The IAEA have to intensified attention on innovative activities
(continued)

3. To harmonize licensing procedures for the new reactor designs

- at the European level - European Utility Requirements

- at the OECD level – Multinational Design Evaluation Programme (MDEP)

Global Nuclear Order in the Context of Nuclear Renaissance

Goal of the global nuclear order is to ensure access for all countries to nuclear technology benefits in safe and secure manner

To achieve this goal it is necessary:

- **Establishing and maintaining uniform requirements to necessary infrastructure for all involved (especially for newcomers)**
- **Safety and Security harmonization and synergy based on fundamental safety principles (defense in-depth approach)**
- **Friendly environment and transparent rules for all players**