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International Nuclear Fuel Centers in the Global Infrastructure of Nuclear Power (Technological Aspects of the Problem)

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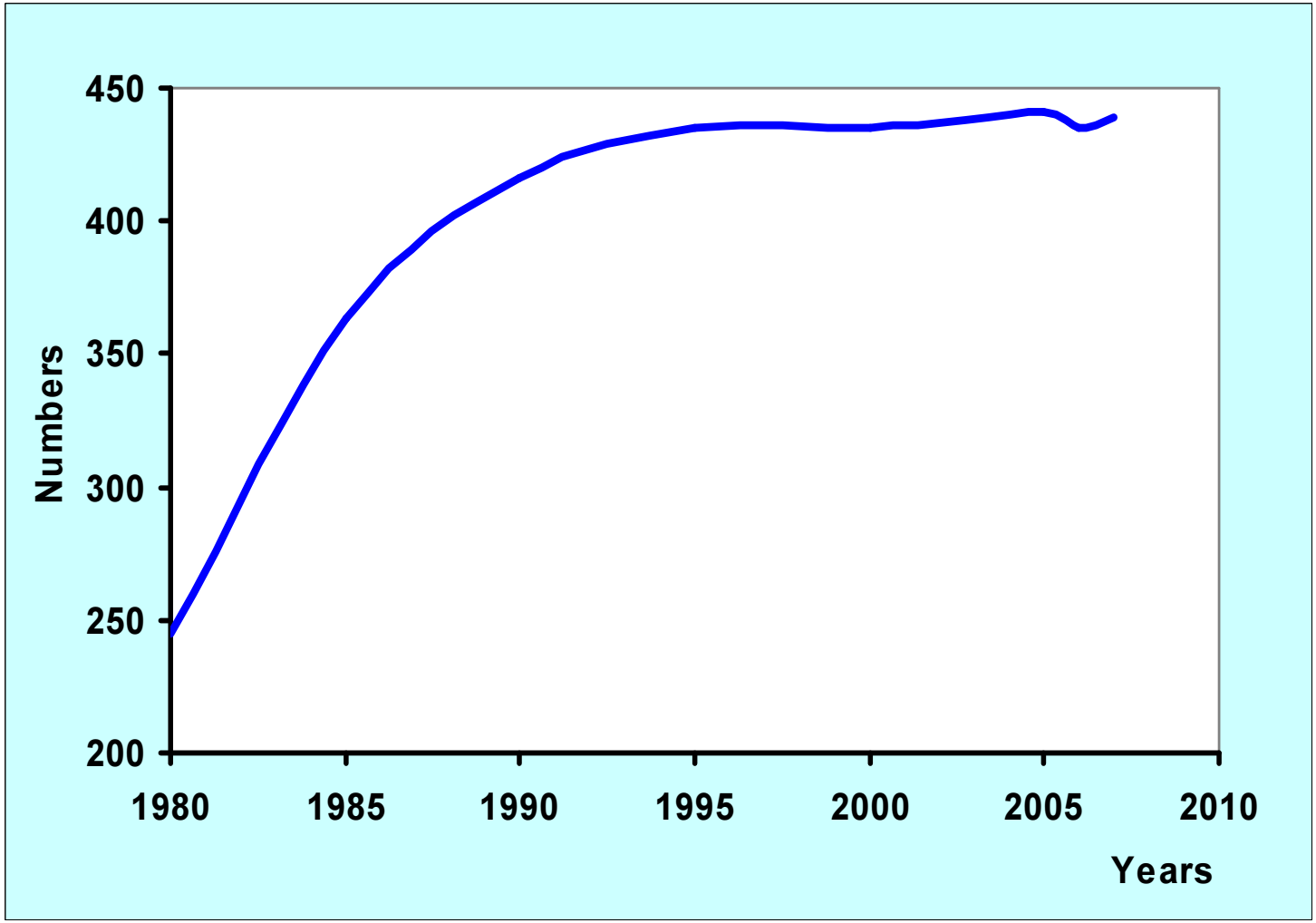
Introduction

- Renaissance of “interest” to use nuclear energy.
- Awaiting increase of number of newcomers throughout the globe.
- Possible temptation to use nuclear power technologies for another applications.
- Increase of proliferation risk.
- Economic burden for newcomers.
- Developed countries may and should assist newcomers.
- Initiatives to decrease risk of proliferation under new conditions in the world.

1. Status of nuclear power in the world

Nuclear Power Reactors in the World



Year	Number
1980	245
1985	363
1990	416
1995	435
2000	435
2005	441
2006	435
2007	439

End of 2008 under operation 438 units , totally 371.6 GW(e)
under construction 44 units , totally 39.0 GW(e)
nuclear electricity In 2008: 2597.8 TWh, share 14.0%

Grouping of countries and areas with nuclear power.

- North America: Canada, USA (2 out of 2).
- Latin America: Argentina, Brazil, Mexico (3 out of 45).
- Western Europe: Belgium, Finland, France, Germany, Netherlands, Spain, Sweden, Switzerland, UK (9 out of 29).
- Eastern Europe: Armenia, Bulgaria, Czech Republic, Hungary, Lithuania, Romania, Russian Federation, Slovakia, Slovenia, Ukraine (10 out of 27).
- Africa: South Africa (1 out of 57).
- Middle East and South Asia: India, Iran, Pakistan (3 out of 25).
- South East Asia and the Pacific: None (0 out of 28).
- Far East: China, Japan, Korea (3 out of 11).

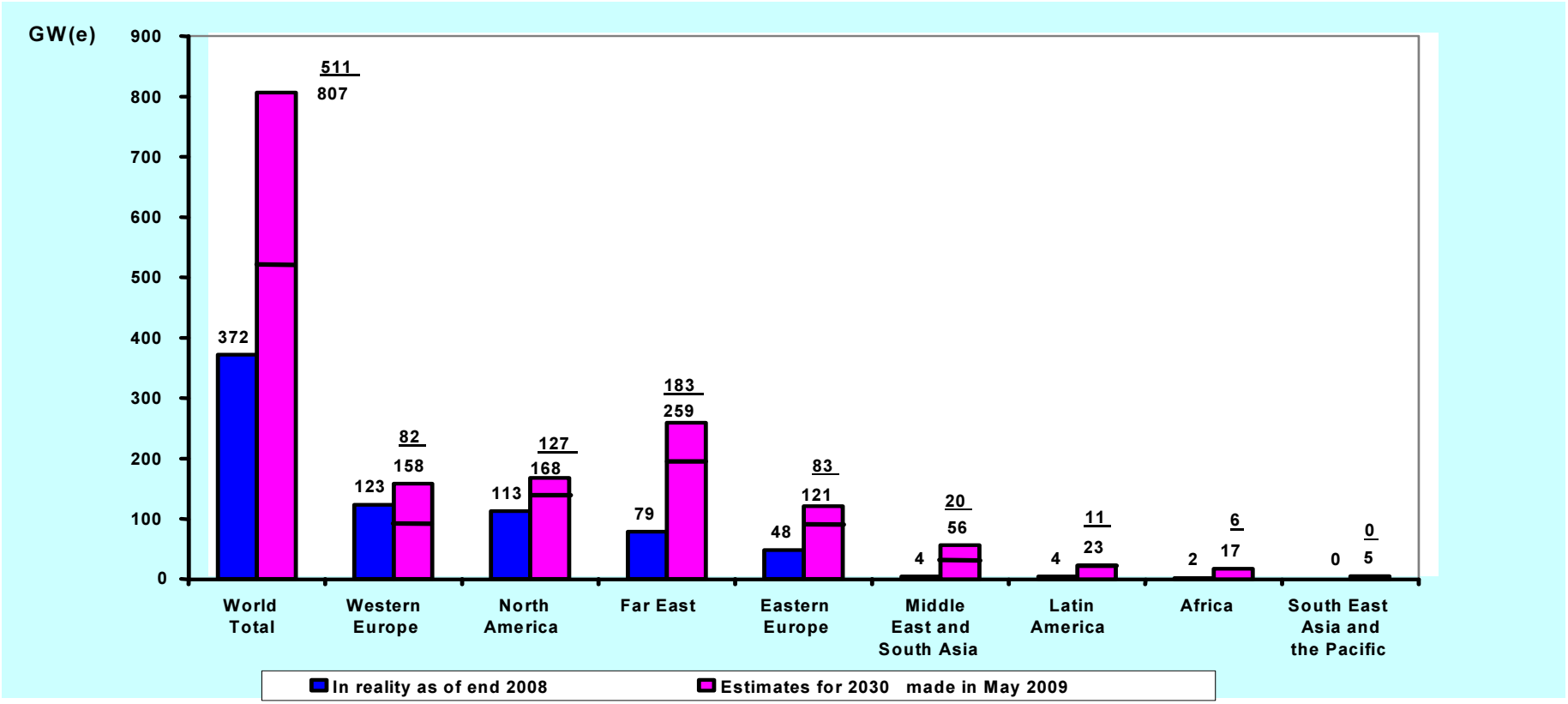
Parameter	Nuclear weapons countries (5+2)	Non-nuclear weapons countries (24)
Number of NPUs under: operation construction	 243 (55%) 25 (57%)	 195 19
Total installed capacity under: operation construction	 208.4 56%) 22.0 (56%)	 163.2 17.0

In total: 31 out of 223

- A few companies: Rosatom (Russia), URENCO, USEC (USA), EURODIF (France), CNNC (China) and JNFL (Japan) enrich uranium on industrial scale.
- A few countries: France, UK, Russia, Japan, India and China have nuclear fuel reprocessing capacities.
- A few countries have advanced fast reactor developments: Russia, France, Japan, India, China and USA.

2. Prospects for middle-term nuclear power development

The IAEA estimates for nuclear power development in 2030, installed capacity GW(e).



Nations considering/planning to add nuclear energy by 2030 or earlier

Latin America: Chile, Peru, Venezuela
Western Europe: Italy, Portugal, Turkey
Eastern Europe: Belarus, Kazakhstan, Poland, Albania, Azerbaijan, Georgia
Africa: Algeria, Egypt, Libyan AJ, Morocco, Tunisia, Guinea, Ghana, Nigeria, Namibia, Senegal
Middle East and South Asia: Bangladesh, Jordan, Yemen, Bahrain, S.A., Kuwait, UAE, Qatar, Oman, Israel
South East Asia and the Pacific: Australia, Indonesia, Malaysia, Thailand
Far East: Philippines, Vietnam, Mongolia, North Korea

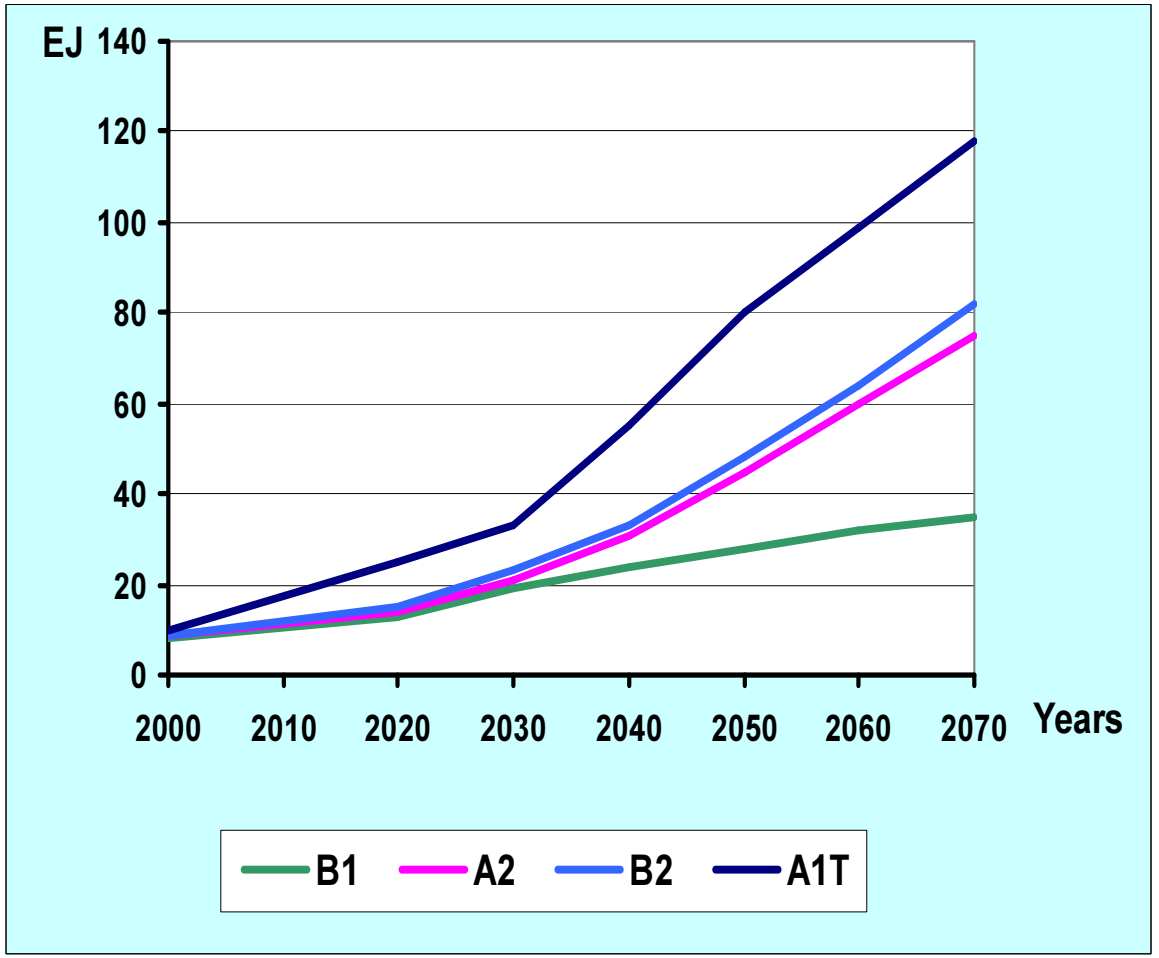
The World Totally: 40

3. Prospects for long-term nuclear power development

Global nuclear electricity production growth for IAEA selected reference scenarios

(*Projected global primary energy use through 2100 in 40 IPCC SRES scenarios, 2000).*

- Scenario B1 by ~1.75 times;
- Scenario A2 by ~ 3.75 times;
- Scenario B2 by ~ 4 times;
- Scenario A1T by ~3.75 times;



1 TW·h=3.6x10^{-3}EJ

In 2008: 2597.8 TW·h=9.4 EJ

By 2030 the number of countries which may use nuclear energy will increase by two-fold as compared to 2008 and might exceed 60 countries.

By 2100 the number of countries which may use nuclear energy would increase by about four-fold as compared to 2008 and may reach about 120.

At the same time it is expected that:

- limited number of countries would have large scale nuclear energy program and commercial level of nuclear fuel cycle infrastructure,
- the majority many of countries will have a few nuclear units in operation with limited infrastructure of national nuclear fuel cycle.

4. Nuclear power main challenges and technological responses

- Economics
- Safety
- Waste
- Fuel resources
- Non-proliferation
- Public acceptance

INPRO, GIF developed requirements to INS. Now it is understood that:

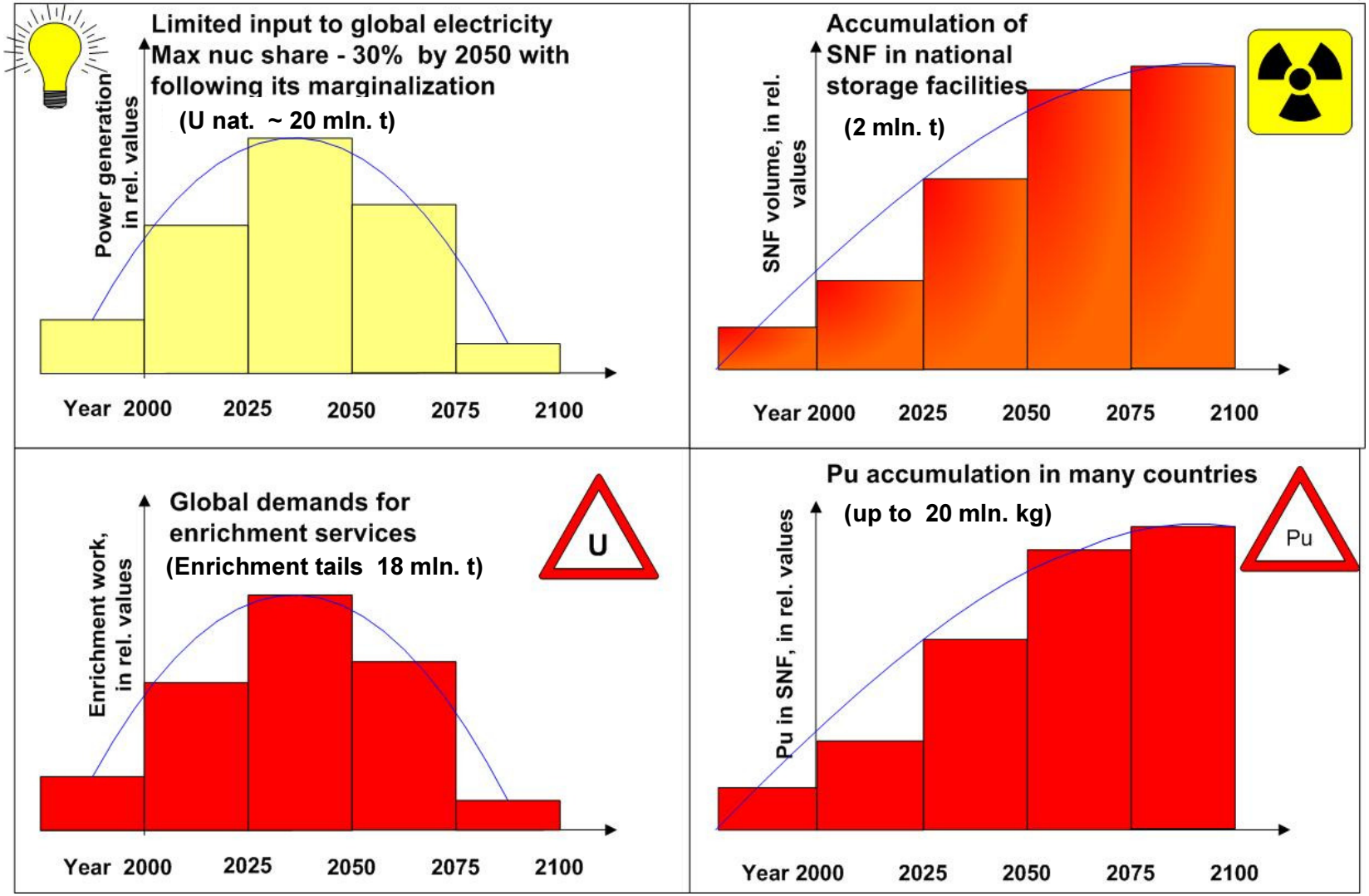
Economics and safety

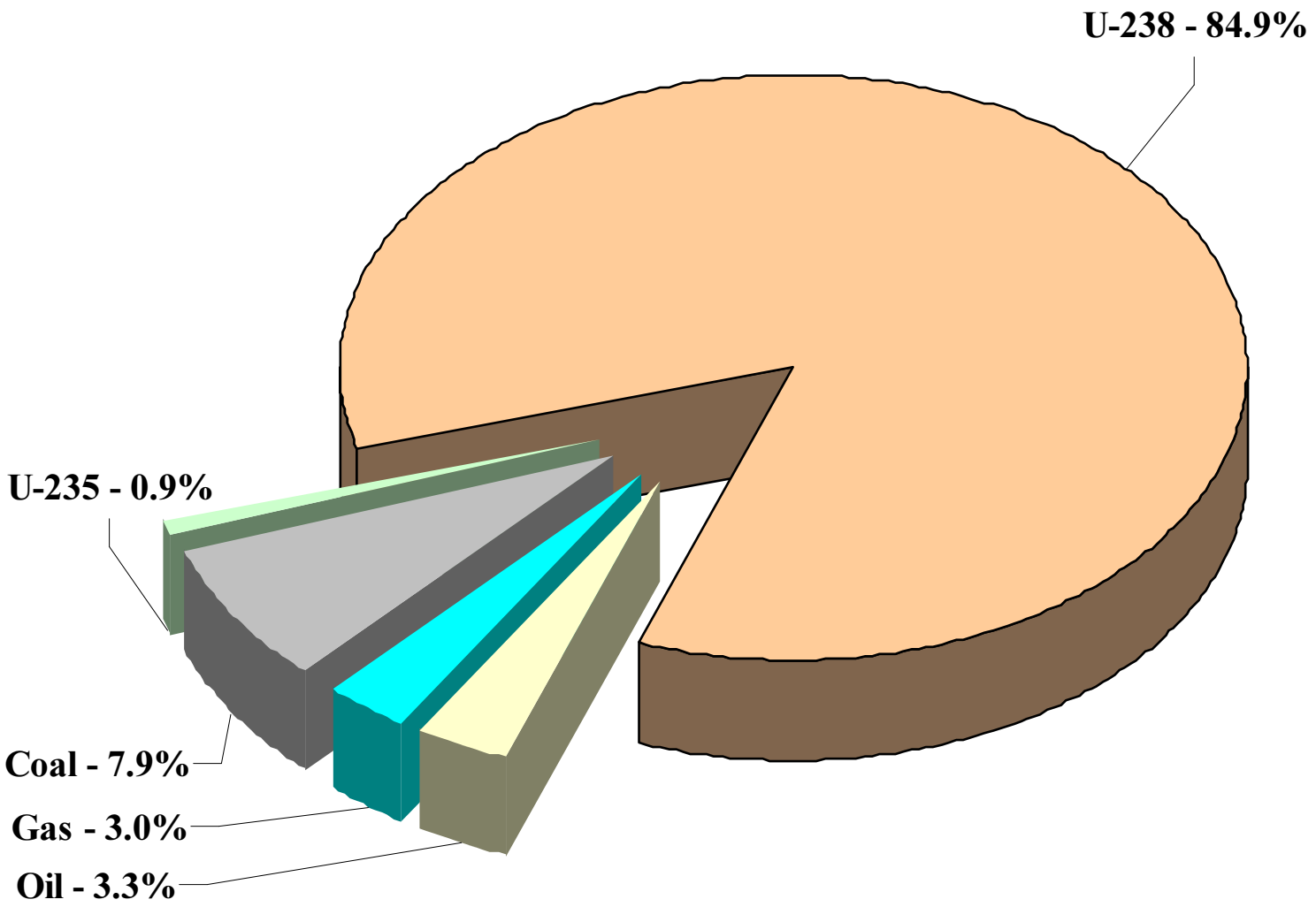
There is no significant technological problem to satisfy economic and safety requirements, being the most important for all countries using nuclear power.

Fuel resources

Fuel resource issue is mostly important for countries with large scale nuclear power program. It can also be solved through development of fast breeder reactors and closed fuel cycle (France, Japan, Russia, India, China)

Challenges for Global Nuclear Energy development on the basis of LWR systems





Relative energy potential of natural resources of the world
(for organic fuel: BP data at end 2008, for uranium: RAR resources 3.3 mln. t., 2005 Red Book)

Waste challenge

- Technological approach exists to address waste challenge important for all countries through final disposal of spent fuel. But this approach may be not acceptable for countries with small territory or small nuclear power, as well as for countries with large scale nuclear power due to economic or sustainability criteria.

- The number of countries with small territory or having few nuclear power units without solutions of spent fuel destiny may increase by three-fold by 2030 and more behind;

- Countries with large scale nuclear program developing fast reactor and closed fuel cycle technologies
  - France, Japan, Korea, Russia, India, China, USA;
  - It is not expected notable increase of number of such kind of countries in coming decades;

- Drawbacks of irretrievable spent fuel final disposal:
  - Loss of fuel resources
  - Loss of energy
  - Creation of “plutonium mines”
  - Proliferation threat - probability for access to “plutonium mines” with time is not zero
  - Large radiotoxicity
  - Danger for the environment for thousand years

5. Challenges in non-proliferation area

- Non-proliferation challenge having global importance still have to be discussed in order to find an appropriate ways to tackle with.
- It is most complicated issue among considered ones because it includes technological, institutional, and political dimensions.

Potential ways of proliferation through civilian nuclear power

- Potentially there are two possible options for proliferation of nuclear weapons:
  - At state level;
  - At subnational or/and terrorist level.
- At state level:
    - Use of nuclear power technologies, facilities and materials for clandestine military programs;
    - Use of nuclear power knowledge in parallel clandestine military programs;
    - Withdrawal from NPT and misuse of nuclear power technologies and materials.
- At subnational or/and terrorist level:
    - Theft of nuclear materials for NED or “dirty bomb” manufacture.

Increase of global proliferation risk

- Increasing number of countries are going to use nuclear energy and possible intension some of them to acquire or develop sensitive nuclear technologies;

- Increasing amount of accumulated spent nuclear fuel in many storages world wide without definite decision of its final disposal/utilization;

- Increasing risk of subnational or/and terrorist organization actions due to spreading nuclear technologies and nuclear materials.

Global challenge:

increase of proliferation risk in particular due to awaiting nuclear renaissance.

6. Responses to decrease global proliferation risk

Looking for technological responses to global nuclear power challenges

IAEA INPRO project main findings:

- Fast reactors in closed fuel cycle would be essential for global sustainable development, but
- No clear vision on global non-proliferation challenge and possible technological solutions

GIF main findings:

- Fast reactor systems - essential from sustainability perspectives
- Introducing technological barriers might help to minimize risk at sub national level, but there is
- No clear vision how to address non-proliferation issues at state level

ElBaradei group on Multilateral Nuclear Approaches - 2005

Objective – to analyze advantages and disadvantages of different multilateral approaches in addressing current non-proliferation challenge

Finding:

Group did indicated conditions, that might reduce incentives of some countries to develop national fuel cycle technologies – this is a possibility to get guaranteed complete fuel cycle services for their NPPs at international level

International Proposals made during 2006-2007

- USA, November 2005. Establish of nuclear fuel reserve.
- RF, January 2006. Initiative of the RF President to create global infrastructure of nuclear power.
- USA, February 2006. Initiative of the US President on Global Nuclear Power Partnership (GNEP).
- WNA, May 2006. Providing reliable supplies in the frame of International nuclear fuel cycle.
- NL, RF, UK, US, GR, FR, June 2006. Concept of multilateral mechanism for reliable access to nuclear fuel.
- UK, September 2006. Obligations towards uranium enrichment.
- GR, May 2007. Creation of multilateral center on uranium enrichment with exterritorial status.

Initiatives made by Presidents of the RF and the US in 2006

The RF President initiative on creation of Global Nuclear Power Infrastructure:

Political component: to address current non-proliferation challenges (at state level).

Technological component: providing guaranteed fuel cycle services first of all in enrichment area, and take duty on utilization of nuclear spent fuel as well in a set of International Fuel Centers.

The US President initiative on Global Nuclear Energy Partnership:

Political component: to address current non-proliferation challenges through lease fresh fuel to reactor countries and take back spent fuel for disposition in fuel cycle countries (2006).

Technological component: creation of nuclear fuel cycle with spent fuel reprocessing and utilization of actinides in fast burner reactors.

Overall assessment of international initiatives from non-proliferation perspectives

- Increasing understanding that non-proliferation challenges (national level) could not be resolved through pure technological solutions particular in near or medium term perspectives.

- Increasing understanding that the global challenge from nonproliferation point of view in conditions of nuclear renaissance will be spent nuclear fuel. "Guarantee of utilization of spent nuclear fuel might be more important factor then guarantee of fresh fuel supply for the nations starting to use nuclear energy. Assist newcomers based on International agreements and supply schemes instead of induce them to develop its own technologies on uranium enrichment and spent fuel reprocessing".

  Russian Academy of Sciences and the US National Academy of Sciences joint report published on September 30, 2008 (Reference to "Platts" news)

- Most promising institutional approach to mitigate non-proliferation concerns today are Russian and US initiatives

7. International Fuel Centers

President Putin initiative on International fuel cycle centers:

To create Global Infrastructure for:

- Broad cooperation in peaceful use of nuclear energy;
- Equal excess to nuclear energy;
- Reliable observing requirements of nonproliferation regime;

System of International centers is a key element of Global infrastructure to:

provide services of nuclear fuel cycle including uranium enrichment and management of spent nuclear fuel.

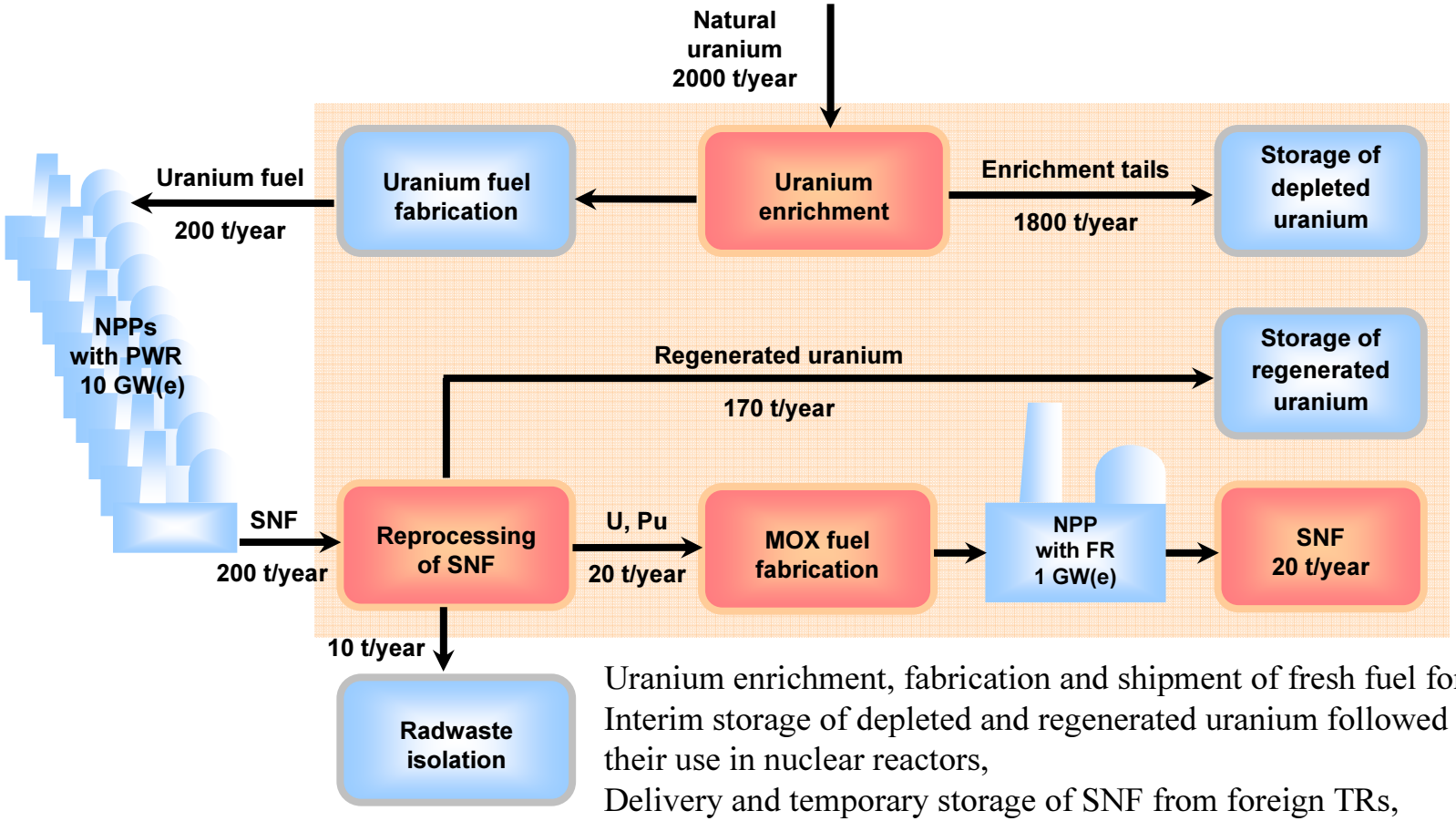
To achieve this goal it is necessary to develop innovative technologies, nuclear reactors and fuel cycles of new generation;

Broad International cooperation is needed.

Principal scheme of International nuclear fuel cycle center.

NP in the Recipient Countries

IFC in Countries Providing Fuel Cycle Services



List of cervices provided by IFC:

Uranium enrichment, fabrication and shipment of fresh fuel for TRs,
Interim storage of depleted and regenerated uranium followed by their use in nuclear reactors,
Delivery and temporary storage of SNF from foreign TRs,
Reprocessing of SNF from foreign TRs,
Fabrication of fresh MOX fuel for FRs,
Irradiation of MOX fuel with electricity generation in FRs,
Interim storage of SNF from FRs followed by its recycling in FRs.

Some practical steps to put forward IFC in Russia

- On May 10, 2007 “Agreement between the Government of the Russian Federation and the Government of Republic **Kazakhstan** on creation of International center for uranium enrichment” was signed.
- “A bilateral action plan to enhance global and bilateral nuclear energy cooperation” was adopted by DOE US and Rosatom Russia at the end of 2006.
  - 7 Russia-US working subgroups were established, one of them is subgroup on the Methodology of Establishing International Nuclear Fuel Service Centers.

- On November 29, 2007 the Government of **Armenia** approved the decision to join International center for uranium enrichment in Angarsk, Russia.

- There are several countries are interested in joining International center for uranium enrichment in Angarsk. Currently discussions are under way with **Finland, Korea, Belgium, Ukraine**. Some more countries are going to consider possibility to join the Center.

- On Sept. 1, 2008 Rostekhnadzor issued a license for management of nuclear materials at Angarsk International Center on uranium enrichment. Before, the Center has been included in the list of juridical persons which can poses nuclear materials (RF President decree, Aug. 25, 2008).

- Russia is ready to guarantee fuel inventory for two fuel refueling of nuclear unit of 1 000 MW(e).

Concluding remarks

During next two decades:

- ✓Number of countries using nuclear energy may double and reach 60;
- ✓Number of nuclear units may be doubled;
- ✓Number of countries with small territory or having few nuclear power units may increase by three-fold.

- By 2100 the number of countries which will use nuclear energy may reach 120, that is half of the total number of countries in the world.

- Only a few of them would have large scale nuclear energy program and commercial nuclear fuel cycle infrastructure;

- Many of them will have only a few nuclear units in operation with limited national nuclear fuel cycle infrastructure.

❖ Increase of global proliferation risk due to:

- Growth of number of countries are going to use nuclear energy;
- Dispersal such countries around the globe;
- Problem with spent nuclear fuel especially in countries with small territories;
- Increasing risk of appear of threshold countries;
- Increasing risk of subnational or/and terrorist organization actions;

- To support non-proliferation regime in new conditions the nowadays activity of the International Atomic Energy Agency and other International Institutes/Agencies should be intensified to large extent.

- New technologies of safeguards, monitoring, and inspections should be developed and applied to cope with this challenge in new conditions.

- Countries with developed nuclear power and its fuel cycle can provide assistance for newcomers and contribute to strengthening of non-proliferation regime.

International Fuel Centers may help coping with all discussed above problems of nuclear power under new conditions of nuclear renaissance.