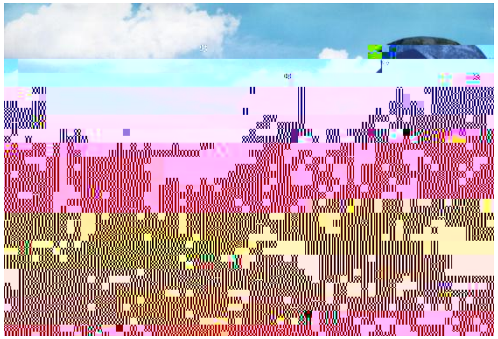
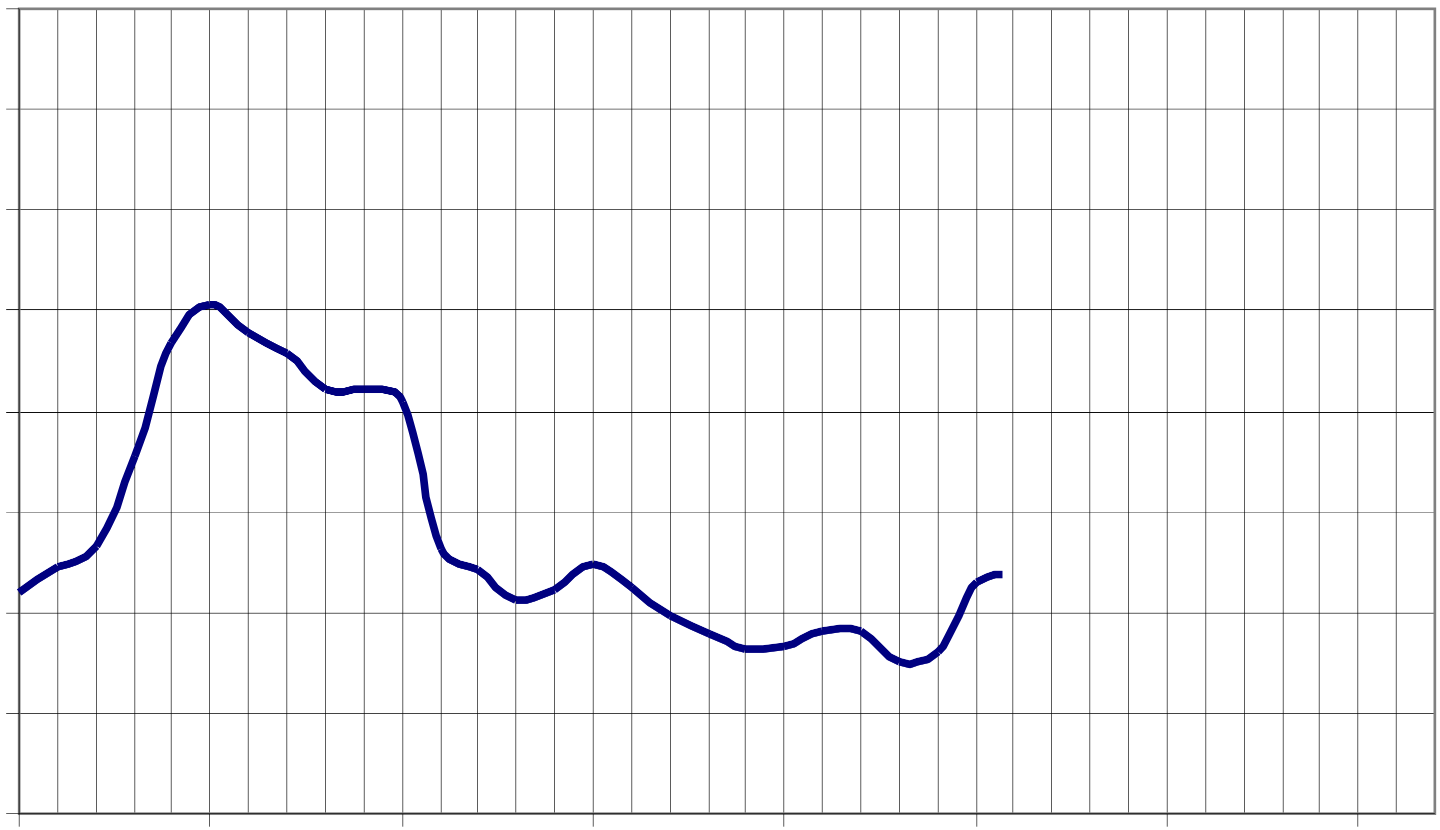
NRC "Kurchatov institute"



FUTURE DEVELOPMENT OF NUCLEAR POWER AND ROLE OF FUSION NEUTRON SOURCE

E.Velikhov

Primary energy share in the world GDP, %



Problems of modern NP

Modern NP cannot be considered as basis of sustainable development for the following reasons:

Inefficient fuel utilization (the effective resource is less, than of oil and gas);

Degradation of neutron potential (consumption of uranium - 235, absence of nuclear fuel breeding);

Accumulation of waste products proportionally energy production (there comes that moment when the electricity tariff will not be sufficient for SNF and RW management);

Limitation of scales and regions of use;

Increase of threat of uncontrollable use of nuclear materials.

Open fuel cycle

2030 y.   600 GWe   2050 y - 1500 GWe

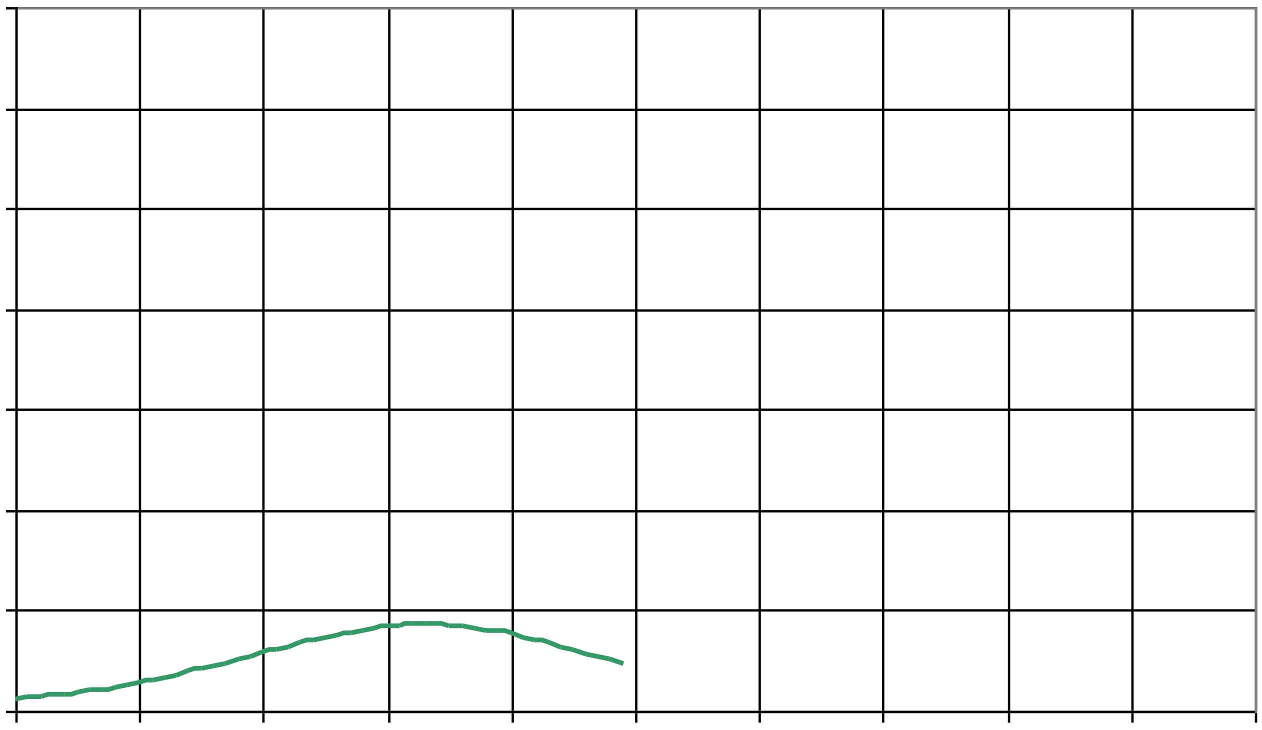
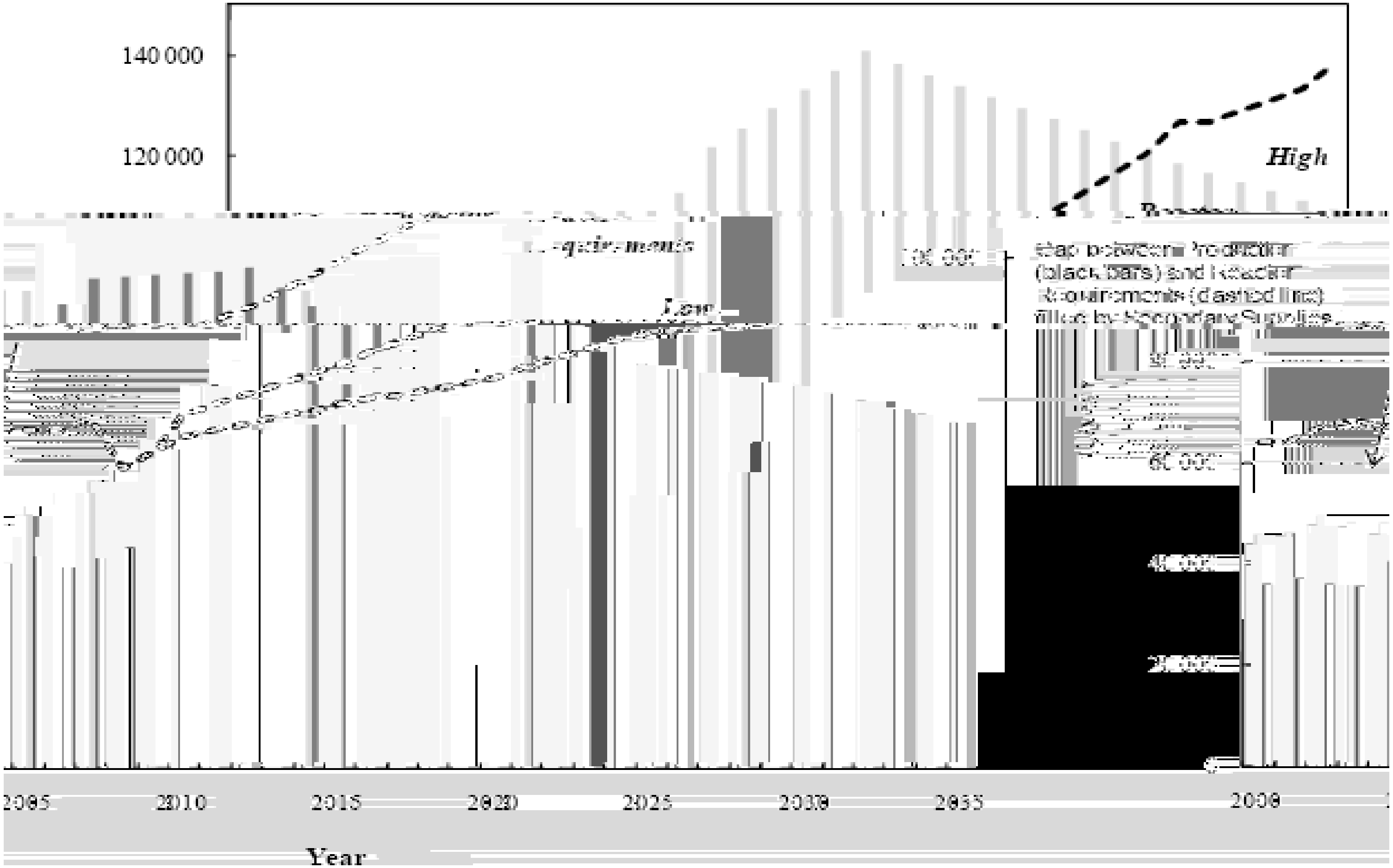


Figure 17. Projected annual world uranium production capability to 2035 compared with projected world reactor requirements*



Uranium 2009: Resources, Production and Demand, OECD 2010, NEA No 6891

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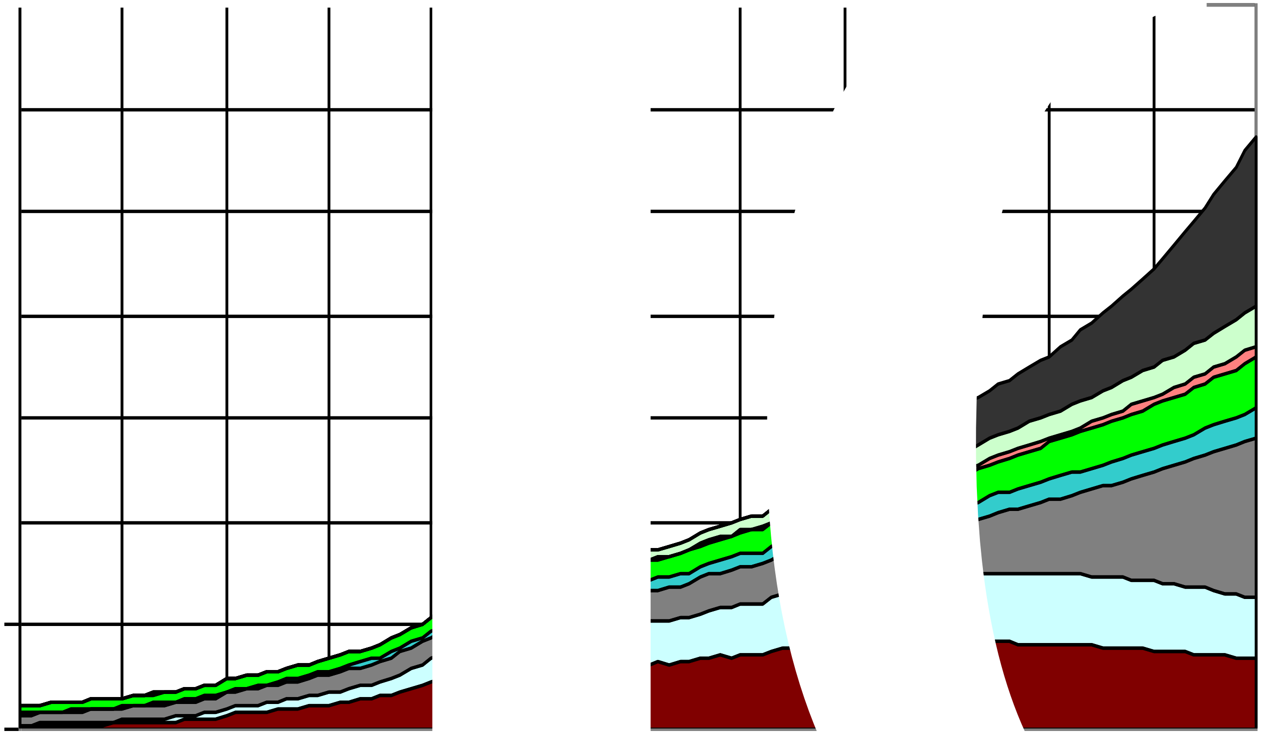
Uranium 2009: Resources, Production and Demand, OECD 2010, NEA No 6891



WAYS
to THE NUCLEAR POWER RENAISSANCE and VITAL RISK FREE REACTORS

The reasons of the current NP stagnation are determined by the existence of **substantial threats and risks** i.e. factors capable of either making the considered technology unacceptable, or/and significantly limit its applicability scope.

Now there are no objective reasons for NP renaissance,
since the basic factors responsible for cautious attitude to nuclear energy are still present, despite all innovative designs proposed in the international framework of GEN-IV and INPRO.
Criteria for selecting the direction of long-term development, as well as the principles for choosing the technological solutions for the future, are still vague.

Several general issues (painful points) seem to cause the most significant doubts in the society impeding the nuclear energy renaissance:

1. non-eliminated threat of disastrous accidents (with high and hazardous for the society uncertainties of their probabilities);
2. weapons-grade material proliferation risks;

3. indefinite risks related to long-term long-lived toxic waste storage;
4. threats of major investment loss in conditions of limited capitals, economic crises and deep inflation processes;

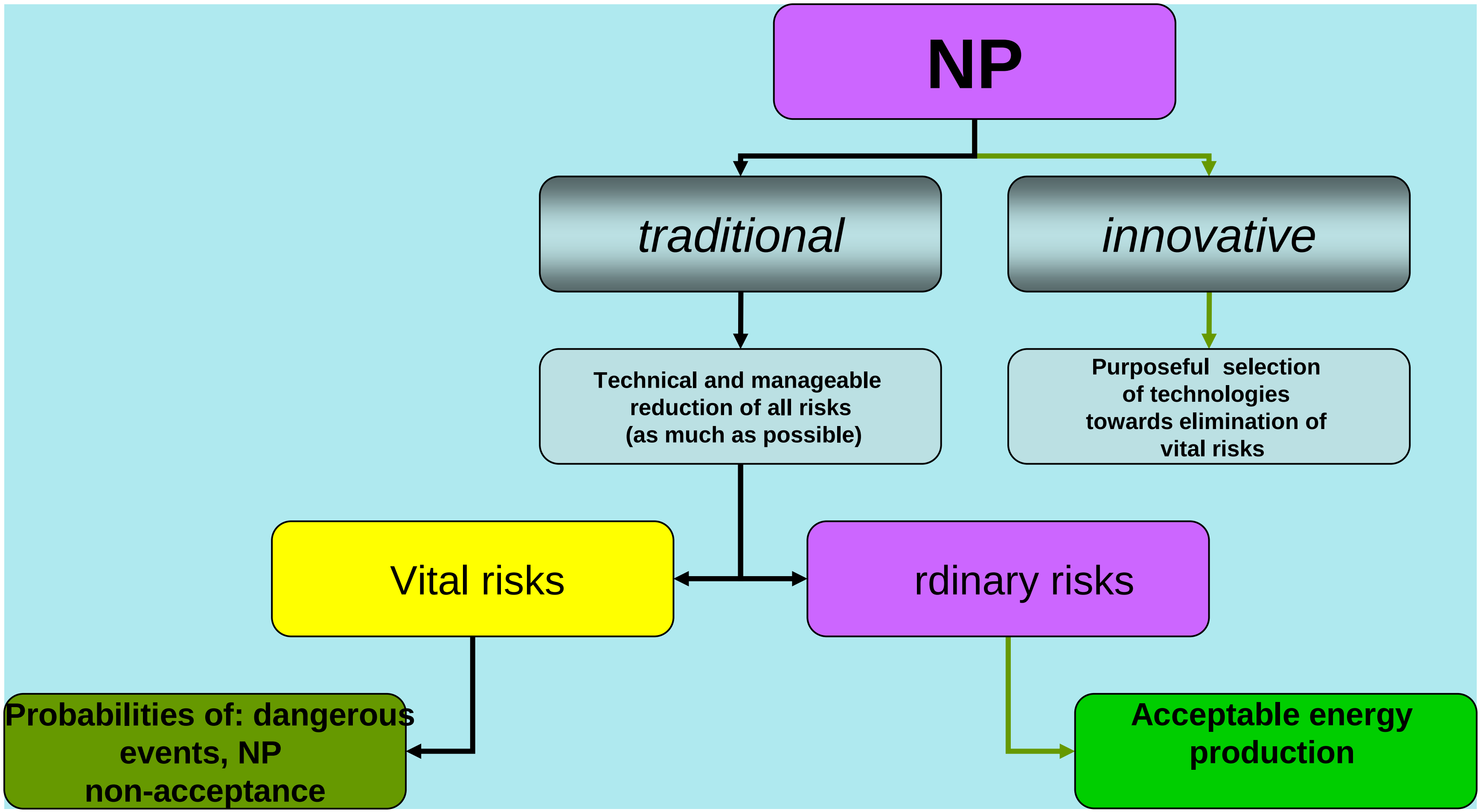
5. “progressive deadlock” effect in NP development scenario caused by the looming nuclear fuel resource constraints.

COMMENTS

All these issues, along with the respective risks/threats they involve, are substantial according to the definition explained above and they are decisive **(vital)** ones respecting the fate of this technology.

Development of an innovative nuclear technology capable of evoking the true nuclear energy production renaissance would necessarily require nuclear reactors and fuel cycles deliberately provided with counter-risk qualities (with known ways of implementation) relative to all vital risks. The available thermal nuclear reactors, as well as ordinary fast sodium-cooled reactors using oxide fuel (such as BN and SuperPhenix), do not definitely possess these qualities.

raditional and innovative strategies and consequences of their applications



1. It would be possible to assure guaranteed elimination of severe accident threats by providing the reactor with the quality of self-protection against destruction (particularly of the core) which is based upon, for instance:
   - *To exclude accidents with uncontrollable dispersal of reactor Transient Overpower (Reactivity Initiated Accidents) - it is possible at the expense of the organisation of its work in subcritical mode with an external source fusion neutrons*
   - *The problem shutdown decay heat removal from reactor can be solved at continuous clearing circulating molten salt fuel from fission products*
   - *limitation of the accumulated non-nuclear energy by the level unable to cause core disintegration in case an accident-initiating event occurs- In system there should not be reserved mechanical (pressure) and chemical (zirconium, sodium) energy*

3. Vital risks of Transuranium wastes + Long Lived Fission Products storage

The task of preserving the radioactive balance at nuclear power development seems to be solvable by using the vital risk free fuel cycle, which should include:

reactors fed with non-enriched uranium;

spent fuel separation from Short Lived (SLFP) and Long Lived (LLFP) fission products;

abandonment of residual actinides' separation from lanthanides and creation the special "workspace" in reactors arranged for burning them (assuming a slow "exponentially type" growth of the reactor park);

partial transmutation of highly toxic long-lived fission products in .

4. Vital risks of investment loss are important

Recently they have considerably increased and still continue growing mainly because of safety enhancement measures. Crediting conditions also became considerably worse, especially in view of long NPP construction time for nuclear industry.

All these factors aggravate the economics and discourage investments even at the level of governmental orders.

The importance of investment risks would level down in case of their essential reduction (twice or more). And this drastic reduction of investment risks coupled with considerable economy improvement would be possible through a significant reduction of NPP construction periods by using factory-made precision autonomous modules, simpler reactor safety means, and cheaper fuel inventories.

5. Vital risk of rapid exhaustion of fuel resources

Elimination all the vital risks is complicated task and considered to be realistic not for all the reactor types known. Analyses show that MSHT are the best suited for this purpose, and this task would be solvable even in the currently available technology framework, on the basis of the novel ideas of MSHT accenting on:

radical improvement of the neutron balance;

use of modular blanket configurations;

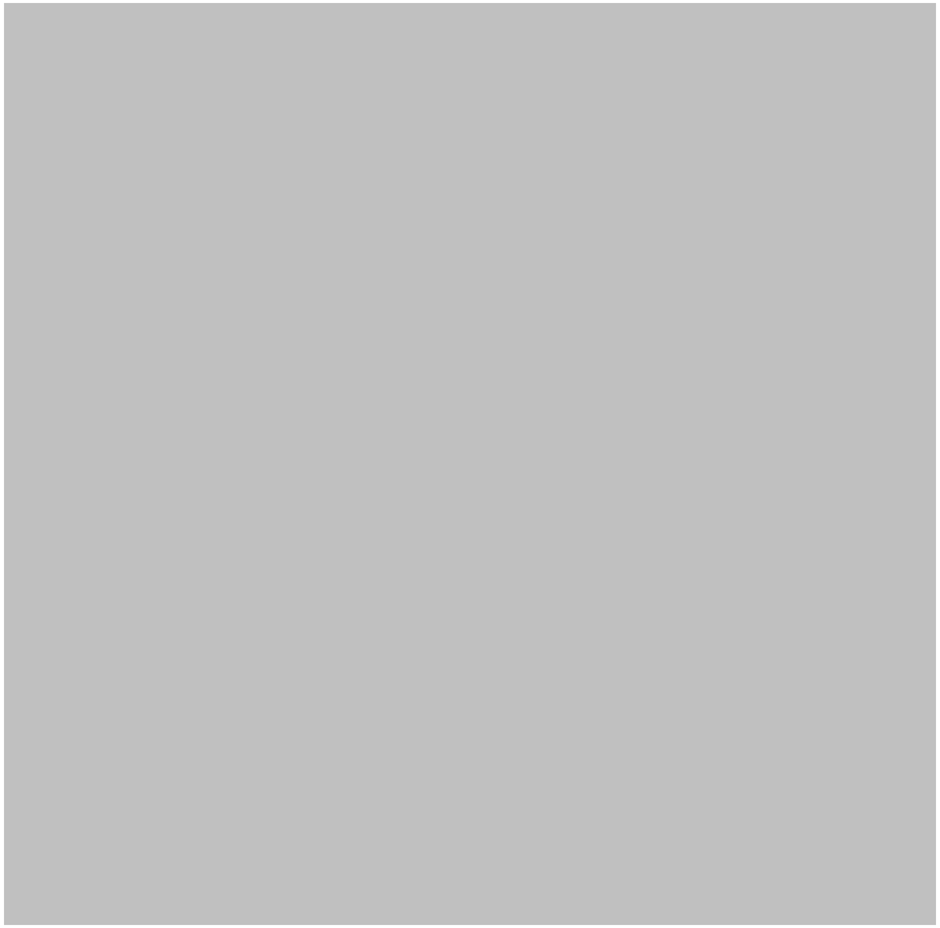
elongation of the fuel residence time respecting the equilibrium mode;

fuel cycle proper rearrangement.

Marketing FEATURES

Nuclear power based on MSHT, would allow possessing possibilities both reactor inventory generation (including fuel reprocessing) and simple power generation (without fuel reprocessing) to be divided between different groups of countries, that would provide nuclear power with complementary security features relative to weapons-grade material proliferation, and contribute to its international marketing flexibility

Reactor DEMO-S



Nuclear fuel production potential

In condition of equal capacity 1GWe

Production in fast reactor

(BR=1.6) **280 kg/GWe year**

FNS **2900 kg/GWe year**

Share of FNS in NE structure should be small.

Nuclear energy with thermonuclear neutrons

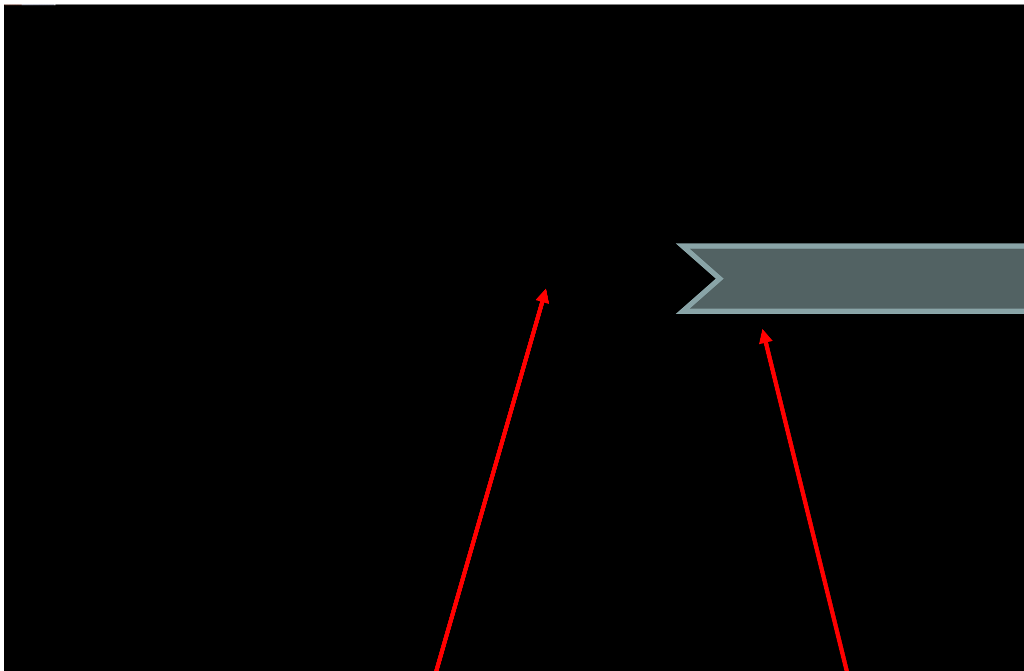
Natural uranium consumption till 2100 10 mln. t

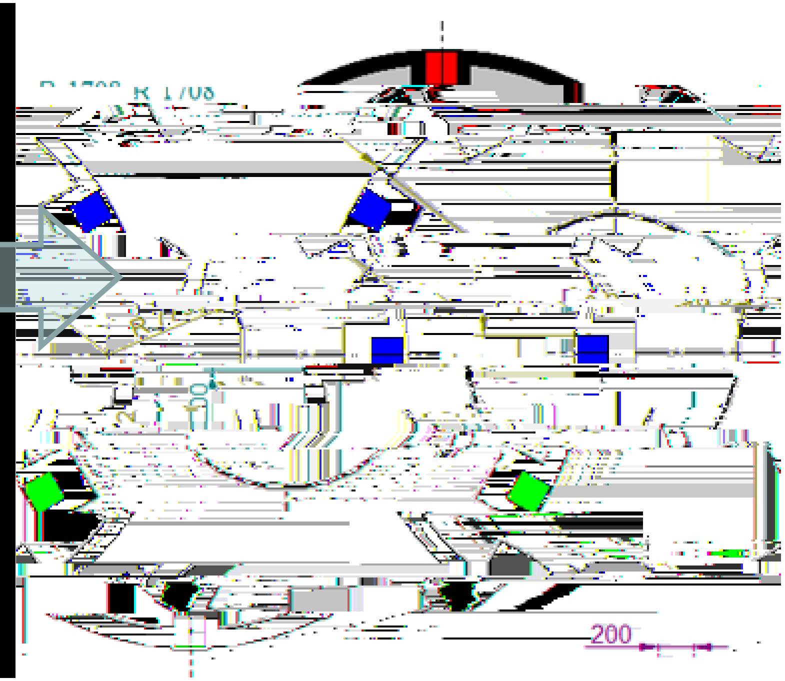
Annual consumption of natural uranium in 2100 - 30

Conditions for placing LSB of TNS

TNS design

TNS model
(equatorial section)





TNS first wall

Poloidal field coils

LST Composition Technology

EXAMPLE: Reduction potentials of An(III)/An(0) and Ln(III)/Ln(0) in LiCl TEJT EMC /P /<MCIBeu-6(t)1

Ln