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Supply of Fuel for Nuclear Power – Present Situation and Perspectives

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At the beginning of a new century we have two different options for the future of nuclear power. One option is to have the same level of nuclear power that we have now. In reality this means decreasing the participation of nuclear in resolving energy supply and environmental problems. However, for people who are more optimistic, as I am, about the future of nuclear power, I think we can not only investigate but also justify another model of development for nuclear, involving large scale deployment of nuclear energy technology. What our predecessors developed 30 years ago is not the only technology which is possible for the future development of nuclear power.

In this presentation I will mainly address the question of natural uranium supplies, mainly as concerns Russia, but with some comments on the worldwide situation. I will also mention the use of MOX fuel, as in September 1998 Presidents Clinton and Yeltsin issued a statement in which they agreed to use for nuclear fuel some weapons grade plutonium from stockpiles of the United States and Russia.

Considering the possibilities for developing nuclear power as a large scale energy source supplying the world, it seems to me that we should use natural uranium only for thermal reactors. We should use plutonium, whether it be weapons grade or from nuclear power plant fuel, only for fast reactors. This includes not only fuel containing plutonium oxide, but also nitride fuel (UN–PuN) in a new generation of fast reactors. Such fuel would have higher density and heat conductivity. These reactors would have a core breeding ratio equal to one, allowing us to deterministically exclude the possibility of a runaway reaction with prompt neutrons, thus excluding accidents such as that at Chernobyl. It would also be important to exclude the uranium blanket from fast reactors, because this is one way to improve the proliferation resistance.

From my recent visit to the United States, I understand that many in that country think that it is possible to use a continuous open fuel cycle for nuclear power. However, the global reserves of natural uranium cannot ensure sustained development of world nuclear power in the next century. When there are no sources of uranium left in the East, they could use uranium from seawater; the resources are around ten times more than we have presently with conventional resources.

What are our uranium resources in Russia? We lost a large part of the resources which we had in the Soviet Union to other countries, and now we

have around 200 000 tU (0.1–0.2% grade). Of course, we are mainly using uranium from stockpiles which we have in Russia, including reprocessed weapons uranium and spent fuel from power and submarine reactors. What are our requirements in the next ten years? Up to 45 000 tU for Russian NPPs and up to 50 000 tU for deliveries to NPPs abroad. The main conclusion from this is that we have enough uranium for the no-growth option for nuclear power, but that we need more to ensure large scale growth of nuclear power in Russia in the next century.

Global uranium reserves amount to 2.3 million tU at a cost below US\$80/kgU, enough for about 40 years at the present level of nuclear power of about 350 GWe with the open LWR fuel cycle. There is also the conversion of weapons grade HEU to LEU for power reactors. Overall, total potential resources of “cheap” uranium can be estimated at about 10 million tU. In later discussion I will use this potential figure to help me estimate the possibility for the further participation of nuclear in solving the energy supply problems of the world.

What is very important is that if we use plutonium in LWRs we only increase the potential of the open cycle by a small amount – if we use both recycled uranium and plutonium we add only 20% to the effective LWR fuel inventory. At the same time we increase the cost per kilowatt hour. Maybe if it is just one cent per kilowatt hour this is not so much in the perspective of 50 years, but it is still an increase. More importantly, we increase the proliferation risk. Furthermore, in the case of single use of MOX fuel in LWRs we reduce the potential to deploy fast reactors by more than half, and with multiple use of MOX fuel we totally eliminate the possibility for large scale nuclear power based on fast reactors. This point is not commonly understood.

Figure 1 shows the potential for nuclear power capacity for the next century, against total electrical generating capacity as projected by the World Energy Council (WEC). If we try to follow the Kyoto protocol on climate change we must arrest the growth in the consumption of fossil fuels, and of course one of the main established alternatives is nuclear. With only LWRs, the participation of nuclear in total power supply is not so great, although maybe if we use seawater uranium it could slightly change this.

Only with fast reactors can we have enough energy from uranium (Figure 2), including the use of uranium-thorium fuel cycles. For those countries which think that the time for fast breeders is 2020 or 2030 it may seem too early to begin now, but let us remember that we have not yet fully developed this technology. Of course we know something about fast reactors, for example in Russia we have experience with BN-350 and BN-600, but I cannot say that what we have developed over the last 30 years resolves all the problems. First of all, it is not competitive, as is well known. Second, in the sodium coolant we have around 50 million Curies of radioactivity, so we do not need a fuel melt to have the same accident as at Chernobyl, only a fire. Third, the blanket of the fast reactor produces nearly weapons grade plutonium.

So, those who think that we have this technology in our pocket and that in 20 years we can just take it out, I think they are making a mistake. We have only 20 years to develop this technology. We must remember that in the last 30 years we did not resolve these problems. If we do not develop fast reactors, there will be no nuclear energy options to resolve the problems of

energy supply and the environment. If we use only LWRs, with an open or a closed fuel cycle, we will exhaust uranium resources and plutonium supplies, and there will be no nuclear energy option for the world.

Now I turn to the second point of my presentation. I completely agree with the statement that now we have much better technology than we did 30 years ago to resolve the waste disposition problem. But at the same time there are questions. What is public opinion on this matter? Does the public agree that we have not so much waste, that we have good technology? No, they do not understand it.

As a scientist in my previous life, I also cannot understand how I can take the results from, say, 50 years and extrapolate them for 10 000 years. There are no scientific methods which show us how to extrapolate such results. In Russia, we have adopted quite a different approach in the last seven or eight years to investigate this subject. We ask ourselves, is it possible for the world to have large scale nuclear energy? By large scale, I do not mean the same as we have now, with around 5% to 7% of the total energy balance. This is a very small contribution to resolving the energy problem. Large scale is, for example, 30%, 40% or 50%. At this scale we could really resolve not only the energy demand problem, but also environmental problems.

The question is, if we have such a level of nuclear energy, is it possible to manage the waste, particularly the spent fuel? Can we keep the same level of radioactivity as we had before we developed nuclear at all? The answer is yes, if we have the closed fuel cycle, we have the possibility to keep the same level of radioactivity. This means achieving a balance between the radioactivity of the waste being buried and of the uranium extracted from the earth. The waste should contain no more than 0.1% of the plutonium, americium and curium found in spent nuclear fuel, and up to 1% of the caesium-137, strontium-90, technetium-99 and iodine-129.

Figure 3 shows the activity of high level waste after reprocessing (curve 1), and the activity of the raw materials which we excavate from the ground. It is possible to reach an equilibrium between these after 200 years, because now we are very inefficient in our use of raw materials. If we improve the efficiency with which we use uranium it will increase this time to around 400 years. A few hundred years is quite different from 10 000 years. There are scientific methods to extrapolate the results and to justify the waste storage methods over such a time scale. If we go to the public and say we will keep the earth the same as God created it, we have a good argument, maybe the same argument as greens use in such discussions.

Some points about MOX fuel. As you know, it is a very hot potato now for Russia. For countries such as France it is a normal technology as I understand, but in Russia we have only limited experience with MOX fuel in fast reactors and we really have no experience with MOX fuel in LWRs. Maybe that is a mistake, and yesterday I agreed that we will investigate this very carefully with Cogema and Electricité de France. Our perception is that MOX fuel is more expensive. Maybe this is not the case, but if it is we cannot use MOX fuel in LWRs given the economic situation in Russia. If it is a political goal it must be supported by financial resources.

The absence of MOX fuel fabrication enterprises in Russia and of nuclear reactors licensed to use this fuel means there will be significant expenses to include weapons grade plutonium in the nuclear fuel cycle. For fast reactors, the first stage is now ready for demonstration and will involve 18 MOX fuel assemblies in BN-600. In the second stage 20% of the fuel in BN-600 will be MOX fuel; this requires further R&D. The use of MOX fuel in thermal reactors will require financial and technological input from the world community.

What I am saying about the future of nuclear energy is normal for a scientist, but it is the opposite of the position of the main political actors in the nuclear theatre. In Russia, and in France, Germany and the United States, because so much money has been invested in existing technology there is no interest in changing the direction of nuclear development. In my understanding, governments must return to the position where, if they see the future role of nuclear energy, they must provide it with support today and only in 10 or 20 years should they return it to the commercial arena. This is the very opposite of the position of many countries, which feel that the role of the IAEA now is mainly inspections and proliferation control. I think that the role of the IAEA should be the same today as when our predecessors set up this very important organisation, that is to develop nuclear energy in the world and at the same time to guard against proliferation.

In conclusion, let me return to my two options for the future of nuclear power. If we follow the first option, the no-growth option, we need around seven million tonnes of natural uranium – I think that this is not a problem, it is possible to find these resources in the next century. This would mean a decrease in the nuclear contribution to global electricity production to 10% and below. If we need more than this level of nuclear power, we need quite a different approach. Only through international co-operation can we resolve this problem. Joint development efforts to meet both national and global energy requirements are called for. Russia is ready to collaborate on specific projects already started at the national level.

What I have presented today may not be enough to justify all of my statements, but two years ago we prepared a report for the IAEA conference, which is now open for discussion. It is not the official position of the Russian government, but it is a step in the formulation of our approach for the next 50 years. We also have a report which explains what I mentioned briefly about our radioactive waste policy, that is keeping the radioactivity of the ground the same as before nuclear development began.

The fifty years of available experience would allow reasonably quick development and demonstration of fast reactors and a fuel cycle which would not be constrained by the availability of cheap uranium resources, and which would meet the requirements for large scale use of nuclear power in terms of energy cost, safety, radioactive waste management and proliferation resistance. If the huge potential of nuclear energy is to be realised in the next century, the nations concerned should join forces to develop, build and demonstrate a fast reactor and a fuel cycle tailored to the principles of natural safety.

Figure 1. Tentative scenario for nuclear capacity growth without fast reactors (given potential cheap U reserves of about 10 million tonnes).

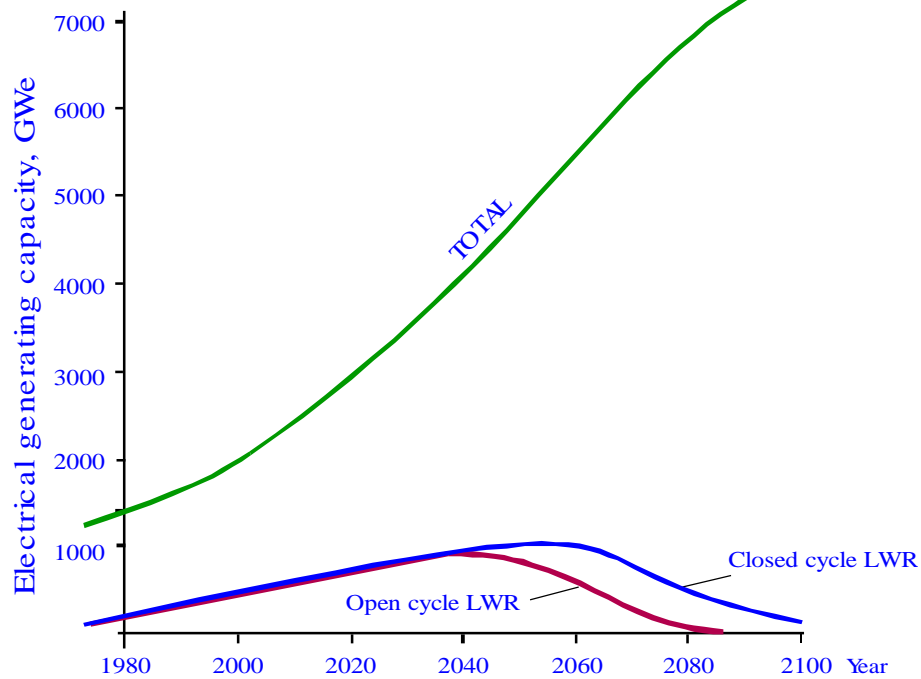


Figure 2. Tentative scenario for nuclear capacity growth with fast reactors (given potential cheap U reserves of about 10 million tonnes).

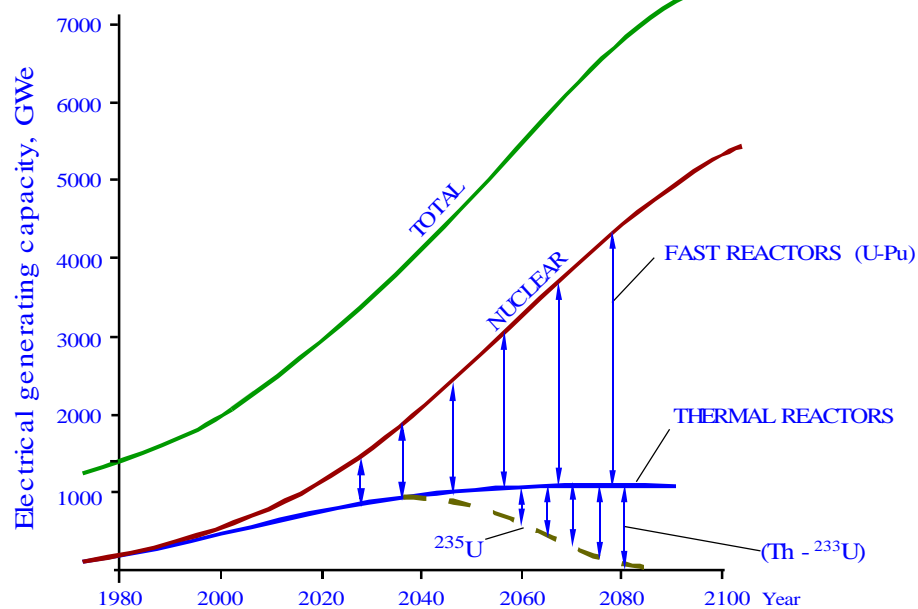
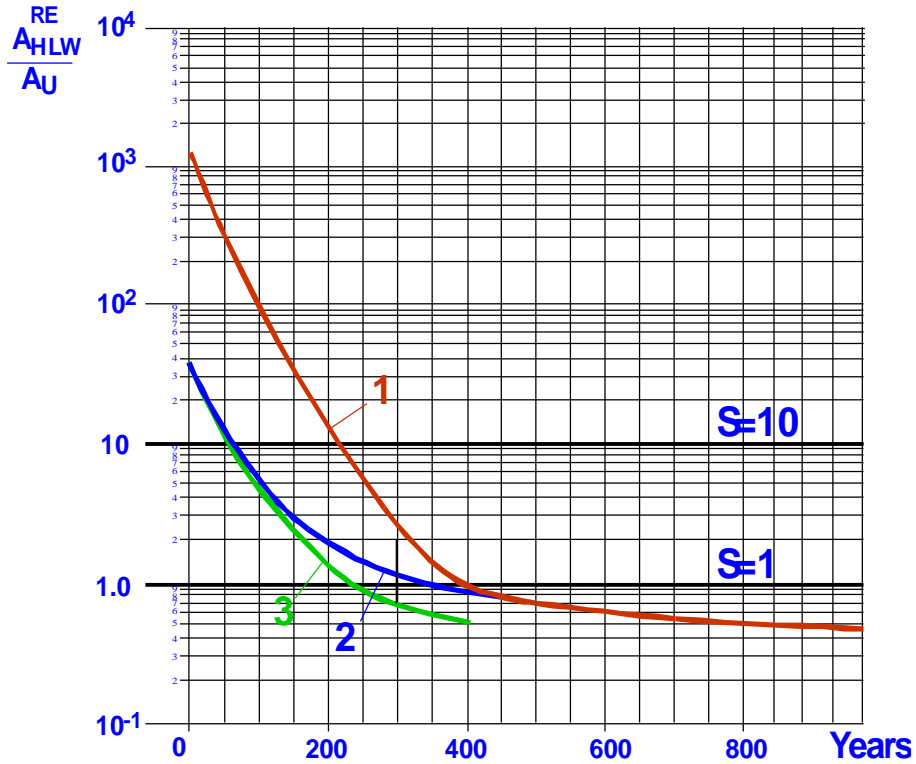


Figure 3. Radioactive decay of waste from the closed nuclear fuel cycle (curve 1) compared with decay of the raw material extracted (ie. uranium ore).



Curve No	Contribution to radwastes, %				
	Sr	Cs	U	Pu	MA (Np+Am+Cm)
1	10	15	0,05	0,1	0,1
2	0,1	1	0,05	0,1	0,1
3	0,1	1	0,01	0,01	0,1