INEA Position Paper
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Is there enough Uranium to fuel the Nuclear «Renaissance» ?

The present world energy context is driven by three major trends: The growth of energy needs to answer the demographic and economic development of the emerging economies, the durable high prices of oil and gas, with a prospective "Peak Oil" not far away, and concerns about their security of supply, and the clear and immediate threat of Climate Change induced by the growing release of greenhouse gases (GNG) of human origin in our atmosphere [2]. The striking recent increase in the world coal production resulting from the first two trends [3] makes the third one even more prominent. There has to be a gradual but significant reduction in the use of fossil fuels, including the transportation sector, for reasons of security of supply, economics and environmental considerations. The only globally available energy system capable of achieving the transition to a reduced fossil fuels use is the electrical infrastructure, with the possibility to electrify parts of the transportation system. Nuclear baseload electrical generation is well suited to provide the large amounts of energy needed for this transition.

Emitting very little GHG over its whole life cycle, Nuclear Power appears more and more to be a necessary part of the solution of this dilemma (though only a part of it), and we do witness signs of a "renaissance" which follows almost two decades of slow growth worldwide. The present situation is not like the immediate aftermath of the first and second oil shocks, when many countries throughout the world were forced to curtail ambitious nuclear deployment programmes, mostly due to financial, regulatory and project management difficulties. Among the industrialized nations, hardly more than half of the planned nuclear expansion was finished between 1970 and 1990, with an operating capacity of 300 GWe in 1990. The largest expansion took place in the US, with almost 100 GWe of installed capacity by 1990, but all orders were cancelled and many constructions abandoned after 1974. Between 1970 and 1990 new nuclear plants were adding around 17 GWe every year to the world nuclear electricity generation. In the 1980s, 218 power reactors started up at an average of one every 17 days, mostly in France, Japan and the United States. Only in Asia was nuclear development pursued aggressively after the mid-nineties, with Japan and South Korea leading. Today, the global financial infrastructure should be better able to handle marketplace changes but the need for energy solutions continues unabated And, with the nuclear power renaissance appearing every day more probable and larger, the same question as during the seventies expansion is being asked: will there be enough uranium available to fuel this anticipated growth of the world nuclear plants fleet over its full operational lifetime? The very steep 2007 peak in uranium prices appears to emphasize fears of impending resource scarcity, even though prices seem to be stabilizing – far above the prices prevailing in the previous decade.

The INEA believes that, despite a short term tightening in the supply demand situation, due to the previous "slump", there is no short term or middle term resources problem. Continued discovery of uranium supplies and recovery from unconventional sources will surely add to the supply, yet it would be prudent to have established fuel reprocessing and recycling capabilities long before demands strains supply. In the long term, however, it will become *necessary to progressively switch to breeder reactors using depleted uranium and, possibly, thorium. To start such reactors, it will be necessary to recover, through large scale reprocessing, the plutonium present in the spent fuel inventories. Alternatively, it is possible to start at least some of these reactors with enriched uranium.*

Given the steadily increasing magnitude of the demand for either reprocessing or enrichment, it is obvious that the sooner breeder reactors are introduced, the less onerous will be the task of adding them to the then-existing thermal reactor fleet and of closing the integrated fuel cycle..

The INEA believes that it is prudent to accelerate the completion of the demonstration of improved proliferation resistant recycling and fast breeder technologies to a globally acceptable and deployable infrastructure capable of commercialization as soon as possible.

Uranium Resources figures, and underlying signification

Since 1965, the OECD Nuclear Energy Agency NEA, later joined by the International Atomic Energy Agency IAEA, publishes every second year a "Red Book" [4] assessing the world uranium (and thorium) resources along 5 categories:

- Reasonably Assured Resources RAR: Known deposits, "reserves";
- Inferred Resources IR : Based on direct geological evidence;
- Prognosticated Resources PR : Based on indirect geological evidence;
- Speculative Resources SR : Extrapolated values;
- Unconventional Resources.

The first two categories, called "Identified Resources" are updated every second year from data supplied by all the major uranium producing countries. Prognosticated and speculative resources are called "Undiscovered Resources" and are much less well known and less frequently updated. Unconventional Resources describe uranium which is not present in uranium deposits but mostly in phosphates or shale, from which it can be extracted as a by-product. In each category of conventional resources, several figures are given according to the expected range of uranium production costs (Table 1).

Cost of recovery $/kgU	Category of Uranium Resources (million tonnes)				
	Conventional				Un-conventional
	Identified		Undiscovered		
	Reasonably Assured	Inferred	Prognosticated	Speculative	
< 40	1.8	1.2			
40 to 80	0.8	0.6	2	4.8	
80 to 130	0.7	0.3	0.8		
> 130	?	?	?	3.0	
Subtotal	**3.3**	**2.1**	**2.8**	**7.5**	
Total	5.5		10.5		15 to 25

The total conventional resources are evaluated around 16 million tonnes, i.e. more than 200 times the world uranium consumption in 2006 (less than 70 000 tU).

It should be noted than since 2006 the figure for identified resources was increased from 4.8 to 5.5 Mt and the total conventional from 14.7 to 16, as a result of renewed exploration efforts launched after the recent and sharp increase in uranium prices.

The short term Supply/Demand situation.

During the past decade (Figure 1), 50 to 60% only of the world uranium consumption was supplied by freshly mined uranium. The remaining, often called "secondary sources", came from excess commercial inventories (around 20%), the recycling of former military material and dismantled warheads, and from materials recovered by reprocessing spent fuel. In that context, uranium prices were kept very low, around 10 $ per lb U3O8 and few investments were made on uranium production capacity, not to speak of exploration. Mines were prematurely shut down much before reaching what would be the cut-off grade under the present circumstances. The total lack of exploration efforts means that the figures in Table 1 reflect mostly the results of exploration carried out in the late 70s and that those figures are certainly underestimated – but how much so? Today, excess commercial inventories are almost exhausted and the contribution from the military materials will diminish in the coming decade. Recycling contributions remain limited for various reasons. Mining production which was "reduced to the bone" has only a limited capability to ramp up.

Since 1986, in a context of cheap fossil fuels and Chernobyl aftermath, the world NPP fleet experienced a slow growth even leading to some political decisions of nuclear phase-out in a few European countries. But recently, for reasons explained above, a strong "Renaissance" is expected and the demand is fast growing.

The resulting supply and demand balance has led to a tightened market which triggered the recent sharp increases in uranium spot prices. This does not reflects any resource scarcity, but an inability of a heavy and heavily regulated industry like uranium mining to adapt to fast demand upsurges.

Uranium Supply Prospects in the Near Term.

Current price spikes have had at least a positive consequence: a new rush for exploration by hundreds of new entrants, the "juniors", and some tens of new production projects to be launched in the coming years. In other words, we shall soon see whether it is easy or not to add significant uranium resources to the currently available picture, mostly inherited from the previous similar period, back in the 70s.

The medium term target for world uranium production is to climb from its present level, 40 000 tU/year, to 60 000 tU/year by 2015 (Figure 2), in order to balance the remaining reactor requirements after deduction of available secondary sources. There is no resource concern at this point but increasing the world production by 50% is not a minor challenge! Obviously, increasing the average energy yield from each ton of mined uranium, through introduction of fast breeder reactors, could alleviate this task.

Uranium Supply Prospects in the longer Term.

Let's be conservative and take for hypothesis the World Nuclear Association WNA's Upper Scenario of 2005 (from 370 GWe today to 740 GWe in 2030, followed by a stabilization at that level), based exclusively on LWR and PHWR. This hypothesis is conservative in that it takes little account of the switch from gas to nuclear which should follow the "peak gas", notably in North America. For instance, the latest "Blue Map" scenario of IEA [5] calls for the building of 32 GWe of nuclear power per year from 2005 to 2050. Under the WNA hypothesis, The annual uranium requirements should escalate from a current 66 ktU/year to 159 ktU/year in 2030. Consequently, the uranium production should ramp up from 40 ktU/y to 150 ktU/y, an even greater challenge.

The cumulative consumption would reach 5.8 million tonnes by 2050, above the current identified resources of 5.5 MtU, and the existing fleet will need roughly the same amount to complete its operating lifetime beyond 2050.

There is a significant likelihood of turning, in time, undiscovered resources into identified resources, and the former may well exceed the present evaluation – unchallenged for years – of 10 MtU. But there is no certainty here. Maintaining reasonably high uranium prices would also prevent the mining industry from shutting down mines before low grade ores are exploited, as happened in the previous decades.

There is also a potential for reducing the demand side of the equation: to obtain a given amount of enriched uranium, one can save on feed natural uranium by lowering the tails assay if the enrichment cost is low enough. One can even re-enrich depleted uranium with high assay by today's standards. Savings allowed by decreasing the tails assay may reach as high as 20%.

But of course, the largest saving possible is the switch to breeders which can extract at least 80 times as much energy from a given amount of uranium as LWR can.

Conclusion

To fuel the existing NPP fleet, uranium requirements amount to slightly more than 2 MtU, well below the current Reasonably Assured Resources (Figure 3).

This existing fleet will progressively disappear by 2040-2050 and be replaced by new reactors on top of new capacity additions. These new reactors will add their lifetime requirements (over 60 years) to the committed resources. In order to fulfil these commitments it appears that, under the WNA scenario, we shall have to :

- Use Inferred Resources by 2015
- Add resources to the Identified category shortly after 2020
- Confirm Speculative resources before 2030

Obviously, more aggressive scenarios imply finding large additional resources shortly after 2030. This evaluation is conservative in that neither unconventional resources nor thorium are taken into account. Nevertheless, reasonable assumptions lead us to conclude that **it will be wise to anticipate supplies tightening before 2050**. Having already a sizeable fleet of Generation IV breeders in operation by 2050 is therefore recommended to ensure a significant contribution from fission to the limitation of global warming for the rest of the century.

References

[1] Update on Uranium Availability; Current and Forecast Mine Production and the Resources Issue. Georges Capus, ICAPP 2007, published in Revue Générale Nucléaire 4, July-August 2007

[2] Fourth Assessment Report. IPCC 2007

[3] Key Energy Statistics. IEA 2007

[4] Uranium 2007: Resources, Production and Demand. NEA / OECD 2008

[5] Energy Technology Perspectives : Scenarios and Strategies to 2050. OECD/IAE 2008

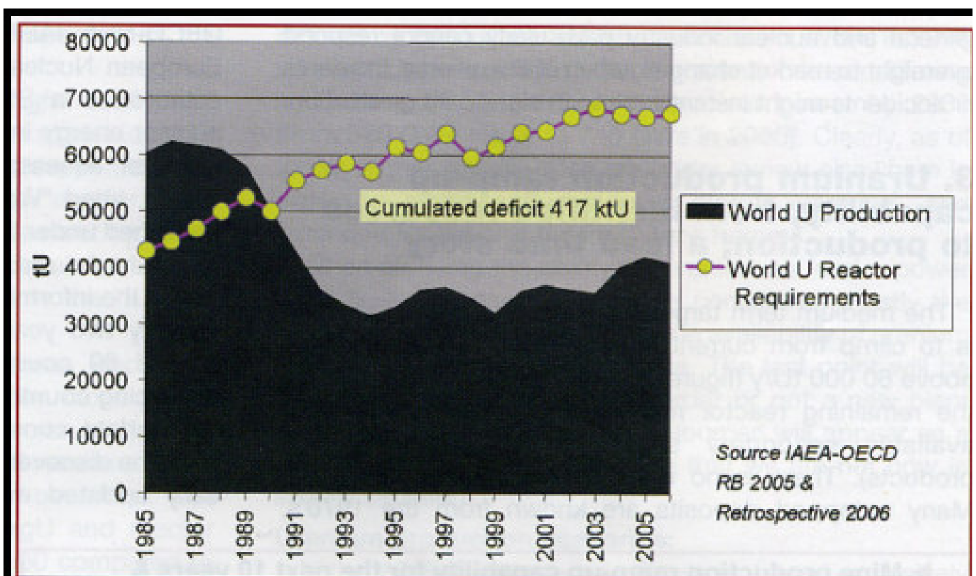

Fig.1 – World uranium production and requirements - Historical

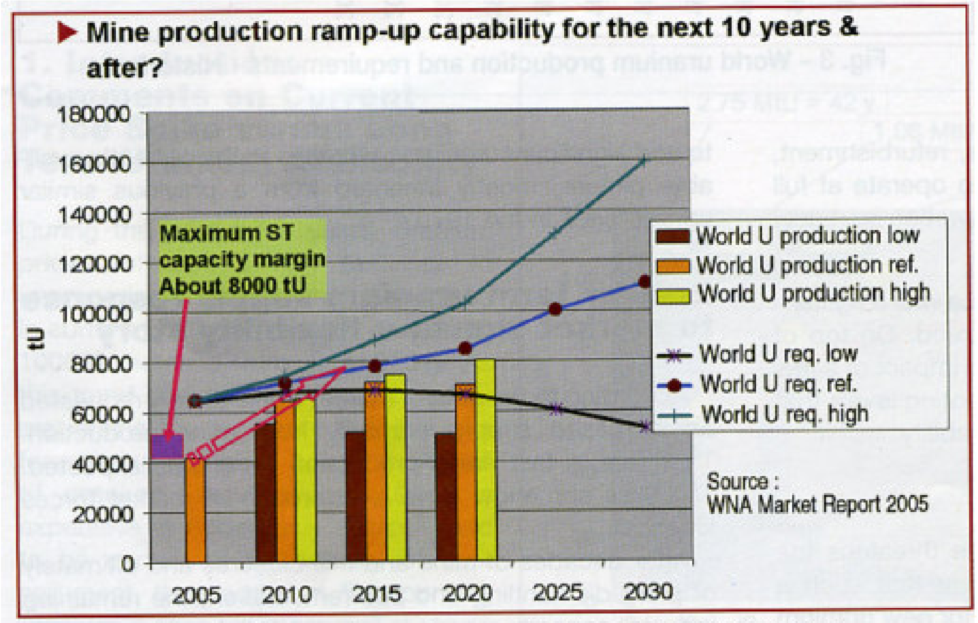

Fig.2 – Forecast uranium production and requirements

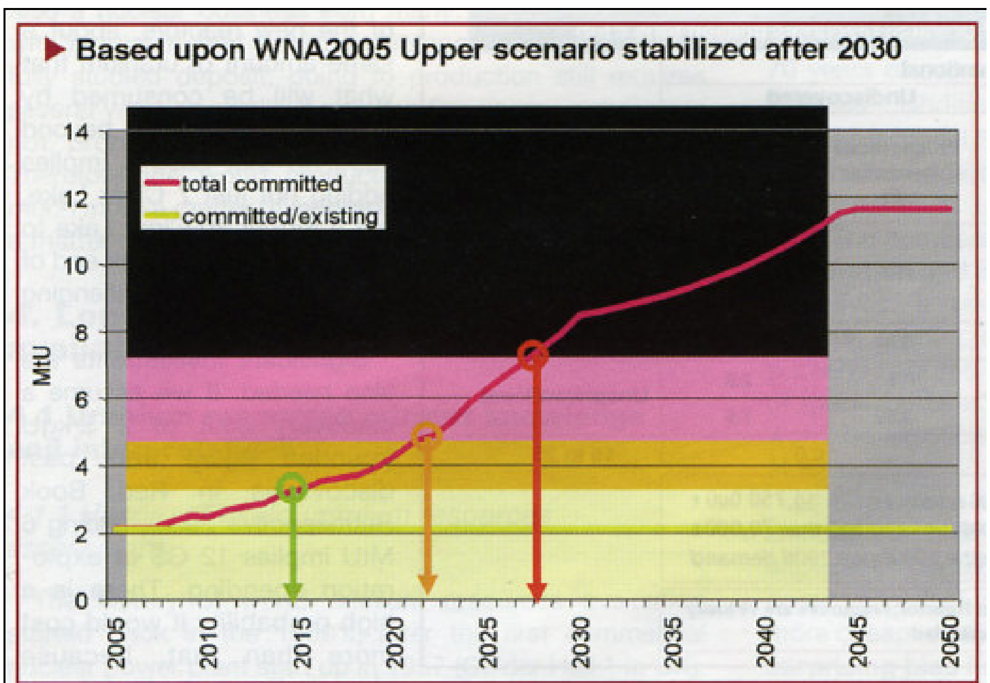

Fig.3 – Trend in uranium resources committed to NPPs lifetime fueling