Civil Plutonium Inventories—Quantities and Uncertainties

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Kevin O'Neill: We'd like to continue now with our next panel, which concerns estimating civil plutonium inventories, methodologies and uncertainties in estimating those stocks.

Our principal speaker on this panel is the IAEA's Jor-Shan Choi. He is a staff scientist in the Nuclear Fuel Cycle and Waste Technology Division at the Agency. He also serves as the scientific secretary for the international working group for nuclear fuel cycle options policies there. In addition, he is responsible for activities in proliferation resistant technologies, plutonium and nuclear materials management. For his current assignment in Vienna, he is on leave from Lawrence Livermore National Laboratory, where he was the deputy program leader for fission energy and system safety program. Prior to joining Livermore he had a very distinguished career in the industry. I turn the floor over to you.

Jor-Shan Choi: Thank you very much for the introductions. As Kevin has mentioned I am currently with the IAEA, on leave from the Lawrence Livermore National Laboratory. In fact, I took over the job vacated by Jim Finucane, so for the past one and a half years, I have been working as a "Finucane-surrogate" at the IAEA.

I will be sharing with you the topic on estimating separated civil plutonium stocks. Basically, I want to extend to you a comparison between the stocks declared under INFCIRC/549, which were so well discussed in the last panel, and estimates that are calculated using open sources. This work was completed by a group of consultants in two meetings in which I was the scientific secretary.

So, before I start, I would like to acknowledge the group of consultants who helped put this work together. They include Mr. Bairiot from Belgium, Mr. Robert from Cogema; Professor Suzuki—the "junior Suzuki" from Tokyo University; and Mr. Berkhout, the co-author of the famous book on the management of plutonium; Mr. Chebeskov, our keynote speaker, was also a member of the group; in addition, we had Terry Tyborowski from the United States Department of Energy; and Lauren Barbour, formerly with ISIS.

So, as usual with the IAEA policy, we always give the credit to the contributing experts from member states, and take all the blame ourselves for all the mistakes.

First, I would like to summarize the plutonium management guidelines, which was covered in previous sessions. The guidelines are adhered to by nine countries, five of which utilize plutonium, primarily in reactors. Three, at this time, store plutonium, and China claims that it doesn't have any civil plutonium yet.

Figure 1 provides an example of the declarations from 1998. The information is available on the internet. The slide shows the declarations made by these nine countries, and the way that they list the declarations: all of the current separated plutonium held at four types of locations—reprocessing plants, fuel fabrication plants, reactors, and elsewhere.

Figure 1: Plutonium Management Guidelines (INFCIRC/549,[1] end of 1998)

	Belgium (12/31/98)	China (12/31/98)	France (12/31/98)	Germany (12/31/98)	Japan (12/31/98)	Russia (12/31/98)	Switz. (12/31/98)	UK (12/31/98)	U.S. (12/31/98)	Total
1. Unirrad., sep. Pu product stored at reprocessing plants	0	0	52,000	0	500	29,200	—	66,100	0	147,800
2. Unirrad., sep. Pu product at fuel fab. plants or elsewhere	2,800	0	11,800	400	3,200	—	—	800	<50	19,150
3. Pu in unirrad. MOX fuel or other fab. products at reactor	1,000	0	6,800	4,800	800	200	—	2,200	4,600	20,400
4. Unirrad. sep. Pu held elsewhere	negl.	0	5,300	1,300	400	900	<50	0	40,400	7,950[2]
Total (1-4)	**3,800**	**0**	**75,900**	**6,600**	**4,900**	**30,300**	**<50**	**69,100**	**4,650[2]**	**195,300[2]**
(i) Pu incl. in 1-4 belonging to foreign bodies	not rept.	0	35,600	not rept.	0	not rept.	<50	10,200	0	45,850
(ii) Pu in any of the forms in 1-4 held in locations in other countries, and therefore not incl. in 1-4.	1,000	0	<50	not rept.	24,400	not rept.	—	900	0	26,300
(iii) Pu incl. in 1-4 which are in shipment prior to its arrival in the recipient state.	0	0	0	0	0	not rept.	—	0	0	0

NOTES: 1. www.iaea.org/worldatom/infcirc/
2. ex-defense production not included

The two rows below the total refer to the stock of plutonium that is held by a country, but actually belongs to other countries. This is the subject of improvement for the guidelines, because, for example, France has declared that it has a total stock in France of 75.9 tonnes.

I would like to make one correction before I go further, with reference to some earlier discussions. The significant unit used by the declaration is 0.1 tonne, i.e., 100 kilograms, not the 50 kilograms that David referred to in answering an earlier question. Hence, I don't think the declaration is intended for safeguards purposes. As you know, 0.1 tonne is many times larger than a significant quantity defined by IAEA safeguards.

I want to make a disclaimer at this point. I do not work for the IAEA Safeguards Department. I work for the Nuclear Energy Department, so what I am doing is really outside the scope of safeguards. Nevertheless, the work which I present here is what interested the Safeguards Department, which wanted to see how well one can estimate the quantity of civil plutonium by using information available from open sources. The direction is always one way—that means we provide the information to Safeguards, but Safeguards never reveals any of the safeguards-confidential information to us.

Now, back to the figure 1. France has declared 75.9 tonnes, and that 35.6 tonnes belong to other countries. So one can subtract the two numbers, and add the slightly less than 50 kilograms that somebody else is holding for France, and one can estimate what France has.

In contrast, one cannot do this for Germany. Germany only declares the plutonium held in Germany, but does not report those stocks held outside of Germany. So even though we know very well that German spent fuel is reprocessed abroad by both Cogema and BNFL, and some of the separated plutonium is stored abroad, there is no exact quantity being reported. So there is some room for improvement in the guidelines.

This concludes a summary on the declarations, for transparency purposes. Now, I will proceed to describe to you how we attempted to calculate separated plutonium inventories.

First, we have to define what it is. The definition of separated plutonium is the following: "Separated plutonium inventory" is the result of the imbalance between plutonium production and plutonium utilizations. "Production" is defined as the plutonium coming from a reprocessing facility, and also recuperations from fuel which is still unirradiated. What I mean is that even though plutonium is already in the fuel—either in MOX or in other forms—but because it is unirradiated, it is still considered as separated plutonium. And also, this includes plutonium recovered from some shut down reactors—Superphenix, for example.

"Plutonium utilization" is strictly defined, in the sense that the plutonium has been used. So, we did not consider MOX facilities as "end users," because there is so much internal recycling of plutonium within the MOX facility, such as plutonium from scraps and recuperated from waste streams. MOX facilities should not be the end user; rather we define reactors licensed to use MOX as end users.

So, how do we go about getting the open-source information? I know that there was interest in this area as described by the questions that were raised in the last panel. So we look into the open-source information from what is out in the open, including those requiring subscription such as the NAC—Nuclear Assurance Corporation—Fuel Trac publication. Fuel Trac provided the quantity of spent fuel reprocessed for both the baseload contract and the post-baseload contract that was signed by the customers with Cogema and BNFL. Also, the Fuel Trac provided the refueling schedules of reactors that use MOX in their cores.

Currently, the MOX used in reactors is not in full core, it is only used as replacement fuel. Roughly, about one-third of that core will be replaced by reloaded fuel.

In addition, our consultants provided much information based on their knowledge and experience regarding MOX use in reactors. As in the case of Russia, Mr. Chebeskov may have provided the same information to our study as that provided to INFCIRC/549.

The parameters to be considered—these are also questions that were raised during the last panel—include the type of reactor used, because—needless to say—the production of plutonium in the reactor depends on it. It also depends on the burnup of that reactor, and the initial enrichment of the fresh fuel that will go into the reactor. These are some of the parameters needed for an estimate of the amount of plutonium produced in the reactor.

The comments from the Cogema expert during the last panel are well taken—you really have to reprocess in order to know the amount of separated plutonium. But in our case, since we have to estimate, we take into account all relevant parameters.

Figure 2 gives some information on the accumulated amount of spent fuel that has been reprocessed at the end of 1998. The figure also gives the type of reactor fuel. So you can see that up to 77,000 tonnes of spent fuel had already been reprocessed on the civil side. Approximately 75 percent of that was reprocessed from fuel from gas-cooled reactors, primarily magnox reactors in the United Kingdom, and some of the earlier gas-cooled reactors operated in France and elsewhere. About 25 percent of the total reprocessed was from light-water reactor fuel.

Figure 2: Cumulative Amount of Civil Reprocessed Spent Fuel (tHM)

Country	Site	Plant	Fuel Type				Total
			GCR	LWR	FBR	MOX	
Belgium	Mol	Eurochemic[a]	19[b]	86			105
France	Marcole	UP1[a]	18,000[c]				18,000
	La Hague	UP2/UP3		12,452	10	9.4	12,471
Germany	Karlsruhe	WAK[a]		180			180
India	Trombay	PP					
	Tarapur	Prefre-1					
Japan	Tokai-mura	TRP		936		10[d]	946
Russian Federation	Chelyabinsk	RT-1		4,000			4,000
UK	Sellafield	B205	40,000[e]				40,000
	Sellafield	Thorp		1,500[f]			1,500
	Dounreay	UKAEA RP			14		14
USA	West Valley	NFS[a]		194			194
Total			**58,019**	**19,348**	**24**	**19**	**77,410**

a Closed Facility
b CANDU, GCR or other
c UNGG
d spent fuel from Fugen
e Magnox
f LWR/AGR
Status: Year end, 1998

But don't be mistaken that, because of the percentage of spent fuel is greater from gas-cooled reactors than from light-water reactors, that most of the plutonium is derived from gas-cooled reactor spent fuel. The burnup for most light-water reactor spent fuel is much higher than gas-cooled reactor fuel. So as a result, there is a much higher content of plutonium in the light-water reactor fuel—roughly about a factor of three to four—than from gas-cooled reactor fuel.

The countries that are currently using MOX or have experience with MOX fuel are given in figure 3. The figure gives the number of reactors currently operating (from the IAEA database), the reactors currently licensed to use the MOX, and reactors that have been "Moxified,"—that is, those reactors that used MOX but were shut down, or those that currently use MOX. The date of first use of MOX is estimated. The figure also shows the licensing limits; for example, France is operating at roughly a third of the reactor core with MOX fuel, which is currently loading with 5.3 percent plutonium.

That will change, because Cogema is looking into an expansion of the MOX-use program. Currently they have 17 reactors that are using MOX, but I think the goal is 28 reactors. When they reach 28 reactors using MOX, I think that is the time when Cogema would like to operate with what they call a "two-year working inventory." At that point the plutonium in the MOX assemblies will be 7.1 percent, I think, rather than 5.3 percent. So, we have to look a little bit in the future and decide whether or not to consider those operating conditions when making our estimates.

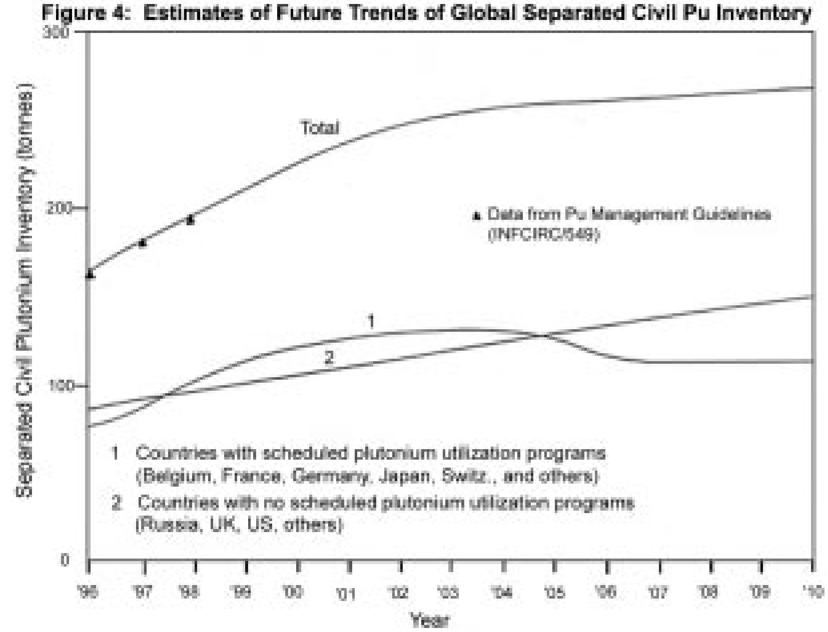
Figure 4 provides total separated plutonium, in tonnes, as a function of year for the next 10 years, terminating in 2010. The total comes from two groups. The first group consists of countries that currently use plutonium in the reactors—that is, those that have an active utilization program. Those in the second group do not have an active utilization program, which means they are currently storing

Figure 3: Experience with MOX-Use in Thermal Reactors

Country	Reactors in Operation[1]	Reactors currently licensed to use MOX	"Moxified" Reactors[2]	First MOX Loading	Licensing Limits, % max, in core	Licensing Limits, % max, Pu conc.[3]
Belgium	7	2	2 (+1)	1963	33	7.7
Canada	16	--	(+1)			
France	57	20	17 (+1)	1974	31	5.3
Germany	21	11	10 (+5)	1966	50	6.8
India	10	2	2	1994	40	undefined
Switzerland	5	3	3	1978	40	undefined
Italy	--	--	(+2)	1968		
Japan	52	3	1	1976	33	13
Netherlands	1	--	(+1)	1971		
USA	107	--	(+6)	1971		

Notes
1. *Nuclear Power Reactors in the World,* IAEA booklet, April 1998 edition
2. (+) number of reactors now shutdown or having lost their MOX licenses
3. Fuel assembly average, except for Japan (highest loaded fuel rod).

Figure 4: Estimates of Future Trends of Global Separated Civil Pu Inventory



their plutonium. The three triangles—located near the "total" curve for 1996, 1997, 1998—show the data from INFCIRC/549. The difference between the two is within a few percentage points. This is good enough for the purpose of estimating the separated plutonium inventory. For next year I can probably put a point along the "total" curve that is close to matching what is to be declared by the nine countries.

You may see that I must have the compilation for every country, and indeed we do. But we are not going to show a country's inventory until it has declared it out in the open. This is the purpose for the next figure that I am going to show you (figure 5). For the last 3 declarations made at the end of 1996, end of 1997, and the end of 1998, the table indicates that China has declared no holding of separated civil plutonium. For France and Japan, our estimates match their declarations quite well. I never expect to be exact, but at least within a few percentage points.

Figure 5: Comparison of Declared and Calculated Inventories of Separated Plutonium

	End of 1996		End of 1997		End of 1998	
Country	Infcirc/549[1]	Open[2]	Infcirc/549	Open	Infcirc/549	Open
Belgium	2.7	1.5	3.6	1.9	4.8	2.1
China	0.0	0.0	0.0	0.0	0.0	0.0
France	35.6	36.4	38.8	39.6	40.3	41.3
Germany	4.9	20.1	6.0	22.0	6.6	25.0
Japan	20.1	20.9	24.1	25.3	29.3	31.3
Russian Federation	28.1	28.1	29.2	29.2	30.3	30.3
Switzerland	0.05	0.4	0.65	0.7	0.0	0.9
UK	51.9	55.5	54.9	58.7	59.8	61.9
USA[3]	4.65	4.65	4.65	4.65	4.65	4.65
Hold for Other[4]	17.6		18.9		19.5	
Total	**165.7**	**167.6**	**180.8**	**182.1**	**195.3**	**197.5**

Notes:
1) IAEA information Circular 549 on "Communications Received from Certain Member States concerning policies regarding the management of plutonium," declared by 9 member states since 1997.
2) IAEA estimates of future trends of global separated civil plutonium inventory, calculated by using open sources in the public domain.
3) Ex-defense plutonium not included.
4) Separated plutonium holding at reprocessing/fabrication facilities that belongs to other countries.

We didn't have good matches with data for Germany and Belgium. It is because Germany only declared plutonium within Germany, and Belgium did the same. Belgium is producing MOX in the Mol facility for other countries, so as a result Belgium has more plutonium in the country than its own.

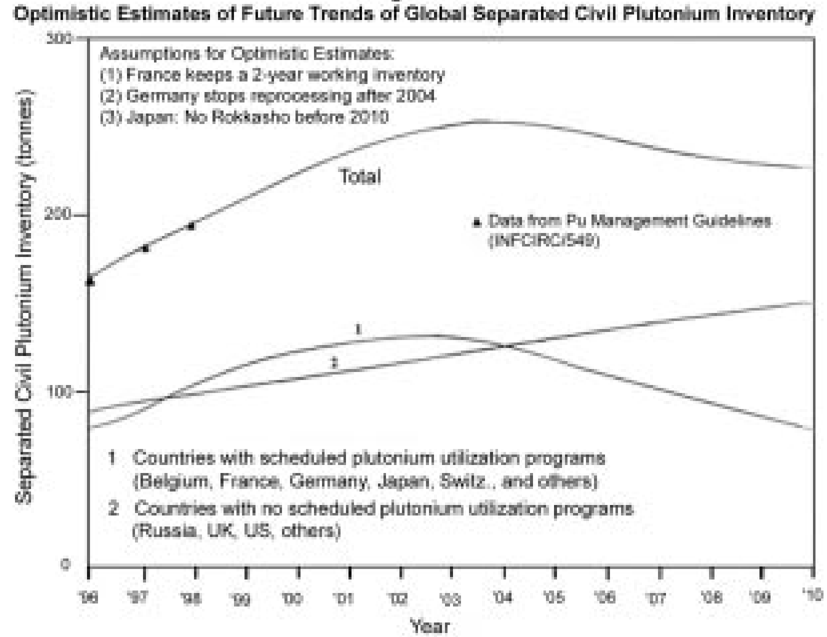
To account for the total balance, one might put all the "hold for others"—as in the German and Belgian situations—and add them up. This is the total declared in the INFCIRC, and this can be compared to those estimated by using open source. The comparison is within one or two percentage points.

Once the methodology is established, one can make future estimates based on the assumptions predicted for the future trend. Figure 6 shows one of the parametric studies that I've carried out.

What makes this future trend of separated plutonium inventory come down? It is based on the assumption that France will reach a two-year working inventory sometime in the middle of this decade, 2005 or so, and also that Germany will not extend the post baseload contract. Germany signed the baseload contract with the BNFL in 1994. It is a ten-year contract—it ends in 2004. But already the Germans are talking about stopping all reprocessing. So it may happen even sooner than that. In this case, assuming that they will not comply with the post baseload contract, that means they will not produce separated plutonium beyond 2004, and MOX will still go into German reactors.That is also a very important point. As the Greens in Germany also call for stopping all nuclear power, one has to raise the issue with the Germans about what they are going to do with the separated plutonium if there are no operating reactors to use MOX. The separated plutonium will be indefinitely stored, just like in UK, and the United States. Will this happen in Germany? That would be interesting to find out.

Also, figure 6 assumes that the Rokkasho plant in Japan will open in this decade. This is a big assumption, because currently the official opening day of Rokkasho is July 2005. But even though you start operating a reprocessing facility, it doesn't reach its full capacity—in this case, 800 tonnes—right away. So you ramp up the capacity slowly—100 tonnes, 200 tonnes, and so on. But if Rokkasho is not available in this decade, Japan may not produce additional separated plutonium, but is assumed to continue to use MOX in reactors. So those are the trends that would pull down curve number 1 in figure 6.

Figure 6:
Optimistic Estimates of Future Trends of Global Separated Civil Plutonium Inventory



Japan, after the criticality accident in Tokaimura, and also because of the current falsification of data from BNFL, is also confronted with the situation that the MOX-use program has been delayed. However, the utility will not wait; it will not shut down for the reactors to accommodate the use of MOX fuel, except during the refueling period.

Therefore, if you miss the reload date, you have to wait for 15–18 months for the next reload schedule. Assuming that the plutonium in MOX was already separated two years ago, the delay will account for another two years. Then, let's say there is another delay because of local objection: One can account for a total of six years, or more, since the plutonium was first separated from reprocessing. This could be a concern because of the in-growth of americium 241 from decay of plutonium 241.

What other issues are we dealing with? I'm coming to the close of my talk, and I would like to summarize a few of the issues on separated plutonium.

First, the inventory will still be increasing, as best I can tell, unless and until some of the variations that I speak about occur. This means that the material will require some indefinite, long-term storage, at least for some of the countries, including the United States. The perceptions on proliferation risk happen there. I don't want to deal with this issue too much, because the organizers have said that this conference is not about proliferation, but rather about separated plutonium.

The increase in the handling dose—this is an important issue that I would raise regarding long-term storage. For example, in the Japanese scenario I described, when that separated plutonium sits on-site for six years, there is some in-growth of americium 241 from the decay of plutonium 241. Now you have an increased dose for your operator. Will Japan send the fresh MOX fuel back to the reprocessor or the fabricator to take the americium out? Also what is the specification for the amount of americium allowed in a light-water reactor core? So that is the issue that has to be considered for this indefinite long-term storage.

The issue may or may not apply to the United Kingdom, which does not currently have an active MOX-use program. How can we encourage the United Kingdom to do something about its separated plutonium? The British don't have light-water reactors, except for the Sizewell-B, that can use the plutonium in MOX fuel. There was some talk about using plutonium in magnox reactors, but this option has not been forthcoming.

A suggestion that I would like to introduce comes from the fact that BNFL now owns Westinghouse, which is the designer of the AP 600. If BNFL will replace every shutdown magnox reactor with an AP 600, then the UK could use the MOX in the AP 600. That would be one alternative—to encourage an active MOX use program, even in a country like the UK.

The other issue is the moratorium on fuel reprocessing. Reprocessing serves at least a couple of issues. I'm not really for or against reprocessing—I just want to lay the technical debates on the table. People would talk about reprocessing in terms of economics. That is one of the important parameters to consider. Let's assume that there is a significant reduction in the reprocessing contracts. Maybe Japan or Germany would like to renegotiate with Cogema and BNFL to reduce the reprocessing prices to make it an attractive option. In the reprocessing plants there are large spent-fuel storage capacities that can be accommodated for interim storage of spent fuel. So actually the reprocessor can act as a regional spent-fuel storage facility. This might be attractive for many utilities because they pay such a high price for storing spent fuel on site or away from reactors. Many proposals have been made, including the Non-Proliferation Trust proposal, which charge on the order of $1,000 per kilogram of heavy metal to store spent fuel. That number has to be considered when compared to the cost that the fuel reprocessor could offer.

The other alternative to plutonium utilization is immobilization. The challenge here is whether or not there are enough fission products that can go into the vitrified glass. Currently—in fuel reprocessing—the plutonium is separated and the fission products are vitrified. If the decision is to immobilize the remaining 200 tonnes of separated civil plutonium, one needs to search for enough liquid high-level waste that can provide radiation protection. That may be a challenge; one may have to de-vitrify the already vitrified glass.

There is a MOX trade option. This means that a country without reactors for MOX use could sell plutonium to other countries. However, there are a lot of challenges to this option from an institutional standpoint. For example, who should pay and how should plutonium cross national and international boundaries?

And the blending of civil and weapons plutonium—we've heard from our keynote speaker that Russia has considered this option. Would that also be an option for the United States? The option has a technical advantage. Most of the experience using plutonium in power reactors is with reactor-grade plutonium. Weapon-grade plutonium, we all know, has higher content of plutonium 239, which presents a challenge to reactor operations. We have not had much of an experience with that.

So those are just a few issues to put on the table, with that I'd like to conclude my talk. Thank you very much.

Kevin O'Neill: The next speaker is David Albright, President of ISIS.

David Albright: I hate to admit that I've been involved in estimating civil plutonium stocks since the early 1980s. I actually look older than I am. Perhaps it has prevented me from aging so rapidly.

I must say first that in various estimates that I've done over the last15–20 years, I'm always struck by how the estimates fundamentally are controlled by political decision-making. The technical uncertainties have tended to fade away as the industry has matured, but the political uncertainties have remained fundamental to any estimate. What I'd like to do in my talk is focus on some of those uncertainties.

I'd also like to reiterate the point made earlier that there are other countries that have plutonium. They pose problems that are typically not confronted in these types of meetings. People in the United States have popularized the term of "orphan stocks" of weapon-grade *uranium*, but there are a fairly significant number of orphan *plutonium* stocks that exist in the world that are not being addressed adequately.

What I'd like to do is focus on two methodologies for doing plutonium estimates, and perhaps a third if there's time. The first two—when combined—are similar to what Jor-Shan presented. But in order to flag some of the uncertainties, I'd like to simplify the methodology, and look at them separately.

The first methodology rests on the basic idea that you separate plutonium, see how much you've got, then subtract out how much you can use, i.e. how much you can make into MOX fuel, regardless of whether the MOX is inserted in a reactor. It's a popular methodology to estimate separated plutonium inventories—I'll show why its not the best way to estimate inventories—but as a first cut it gives you some idea what's going on. Then I'd like to turn to some more country-specific analysis.

Again, my emphasis in the talk is on the uncertainty. Just as a reminder, the countries I will discuss represent those that have significant stocks of civil separated plutonium (figure 1). I don't know how many countries have stocks of separated plutonium—probably 30 or 40, I would imagine—have gram-quantities. In fact, I guess North Korea would say that it only has gram-quantities of separated plutonium, although many experts believe North Korea has several kilograms of separated plutonium. Here, I'm looking at countries possessing at least several hundred kilograms of separated plutonium, and when projecting into the future, we're looking at those with at least a tonne.

Figure 1: Unirradiated Civil Plutonium, end of 1998 (in tonnes)

	Civil Pu owned by that country
Britain	59.8
France	40.3
Belgium	~2.8
Germany	~23
Japan	29.3
Switzerland	~1
Russia	30.3
United States	4-5
China	0
India	0.7
Netherlands	1.2
Italy	~0.5
Sweden	0.83
Spain	0?
Total (rounded)	**195**

As you can see, the nine countries that have been mentioned many times are included in this table, along with others that have also been mentioned today. Again, for clarification, we track plutonium by where it was produced. So when we put together estimates, we just don't take the U.S. declaration at face value, for example. Based on our information, about four or five tonnes of the declared U.S. plutonium was made in civil reactors, and then was subsequently bought or acquired by the Department of Energy. The rest is from military production reactors and declared excess to military needs. So that's the number we're using. Much of that U.S. civil separated plutonium came originally from British civil reactors. We can't just ignore that, because we're also tracking the civil plutonium in Britain, and it would lead us to double-count if we weren't careful.

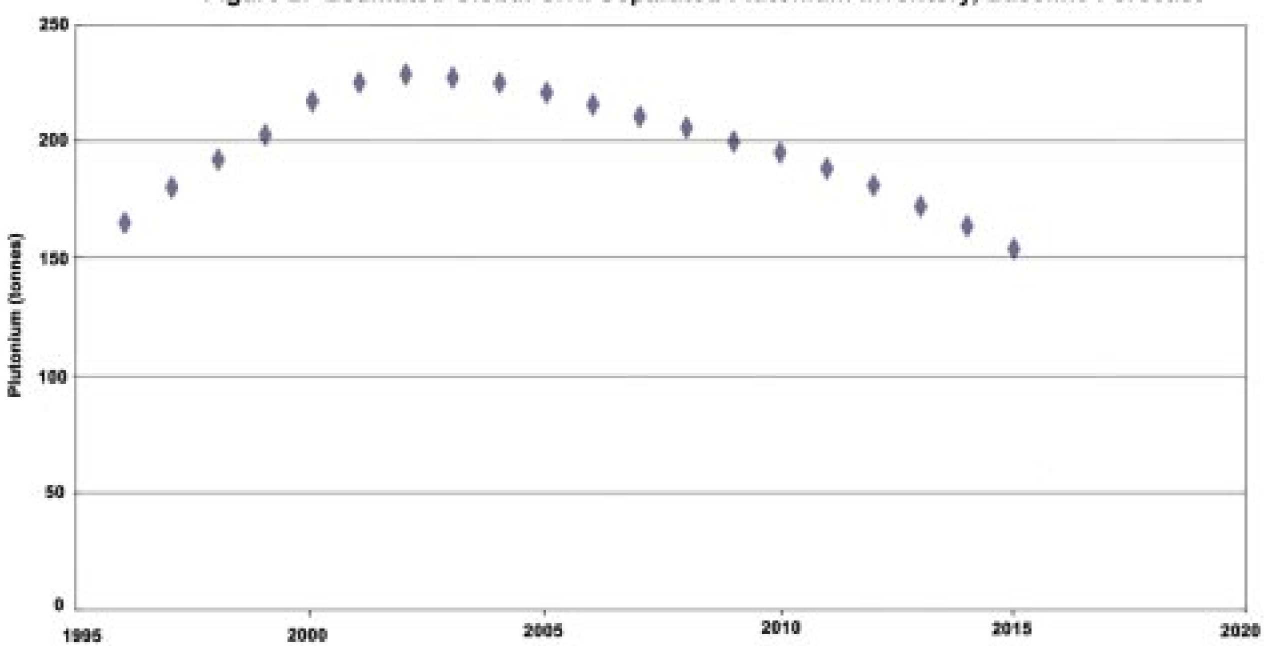
So again, we're not trying to challenge the U.S. declaration, but in terms of our bookkeeping, we use four to five tonnes as the U.S. inventory of civil separated plutonium.

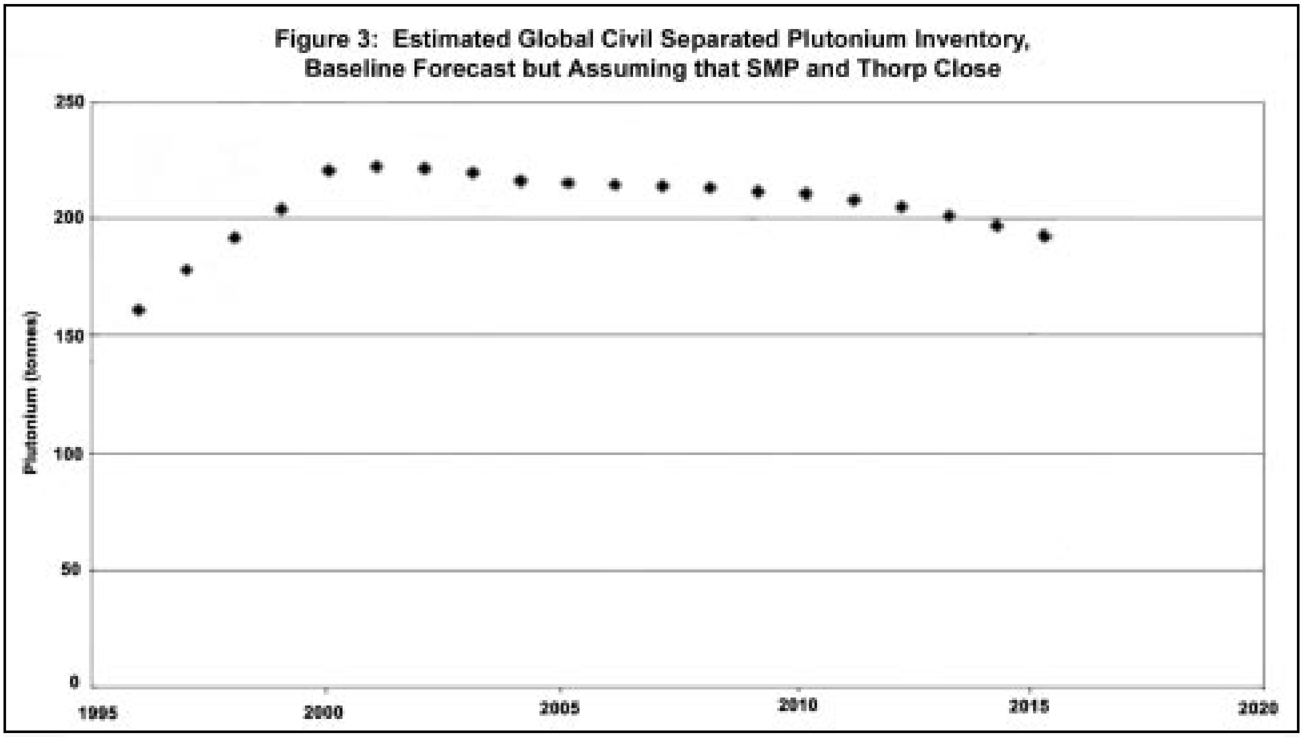
On the first methodology, I'd like to start with a baseline forecast. Jor-Shan had a slightly different one. The following assumptions are those that I'm making to create an initial picture of what could happen in the future:

- Existing reprocessing contracts are fulfilled at the Thorp and UP3 plants;
- The UP2 plant will continue to separate plutonium through 2015;
- The UP3 plant closes in 2010;
- The Rokkasho-mura plant opens in 2007 and slowly ramps up, and a Japanese MOX plant with sufficient capacity is also operating by that time;
- The SMP plant starts in 2001 and reaches a capacity of 120 tonnes per year;
- The Caderache MOX fabrication plant stops operating in 2004;
- The Melox plant reaches a capacity of 160 tonnes per year in 2004. Right now, politically, it's limited to 100 tonnes a year. So in the baseline, I'm assuming that the political situation will change in France, and that the licensing situation for Melox will allow it to go to 160 tonnes a year; and
- The Belgian MOX plant operates at its current capacity throughout the period of the example.

If you do this very simplistic calculation, which ignores reactor use, you see that the plutonium quantities will go up and then start to decrease slowly (figure 2). But still they are quite high. In 15 years from now, we return to where we were roughly in 1995.

Figure 2: Estimated Global Civil Separated Plutonium Inventory, Baseline Forecast





Now I include some of the recent events in the news. Let's say the SMP plant never operates; that's quite possible given what's happening in Britain right now. One can easily understand that if you don't operate SMP, in this simple calculation, the amount of separated plutonium is going to go up. Some in Britain also have argued to shut down the Thorp plant. Again, I include the assumption that Thorp closes. Nonetheless, the numbers remain quite high (figure 3). Relative to the existing amount of plutonium, not much plutonium is going to be separated at Thorp in the future, and SMP has some fairly large fabrication capacity that was fully utilized in the baseline forecast. So if you assume that both SMP and Thorp close, thereby taking them out of the calculation, the net effect is the elimination of much of the ability to bring the separated plutonium inventory down towards 150 tonnes.

Now, figures 4 and 5 on the following page are just for speculation. In figure 4, Melox reaches it's theoretical capacity of 250 tonnes a year, and it actually gets enough plutonium to make this much MOX—in this methodology, I assume that plutonium anywhere could be moved anywhere and fabricated into MOX. Under this case, you can actually start bringing down this inventory quite dramatically. You're still above 100 tonnes by the year 2015, however. Again, one of the points here is that there is quite a bit of MOX fabrication capability out there, if political decisions are made to use it. But I'm advocating neither for nor against that; I just want to point this out.

If France were to make a grand sacrifice, and actually shut down the UP2 plant in 2010, not reprocess any more after that, and continue operating Melox at 250 tonnes a year—figure 5 shows the numerical game you can play. You could bring down the inventory close to what most would consider the best you're going to get.

Despite the last two cases, the current situation does not lead one to be optimistic that these inventories are going to come down significantly. They could come down quite a bit if the decisions were made to do that. But based on what's going on now, one has to be a little skeptical that that would happen.

Figure 4: Estimated Global Civil Separated Plutonium Inventory,
Baseline Forecast but Assuming Melox Reaches 250 tonnes MOX/Year

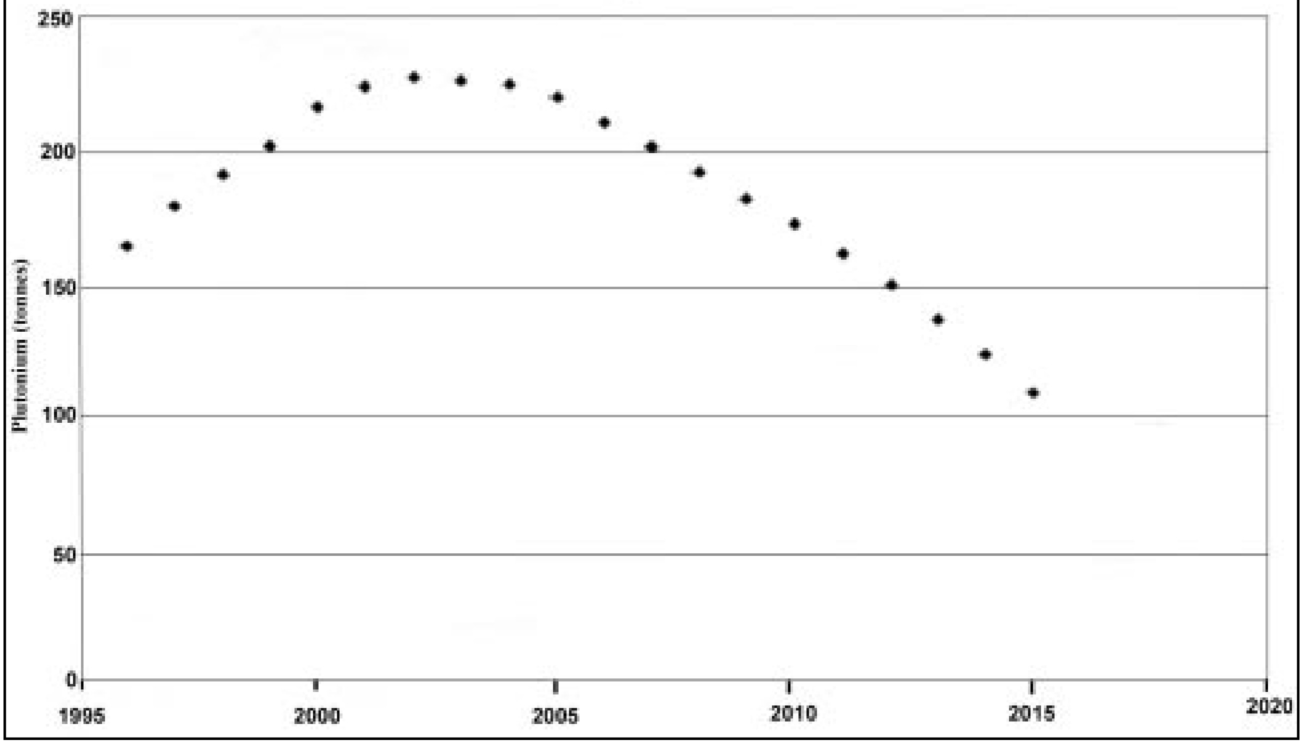
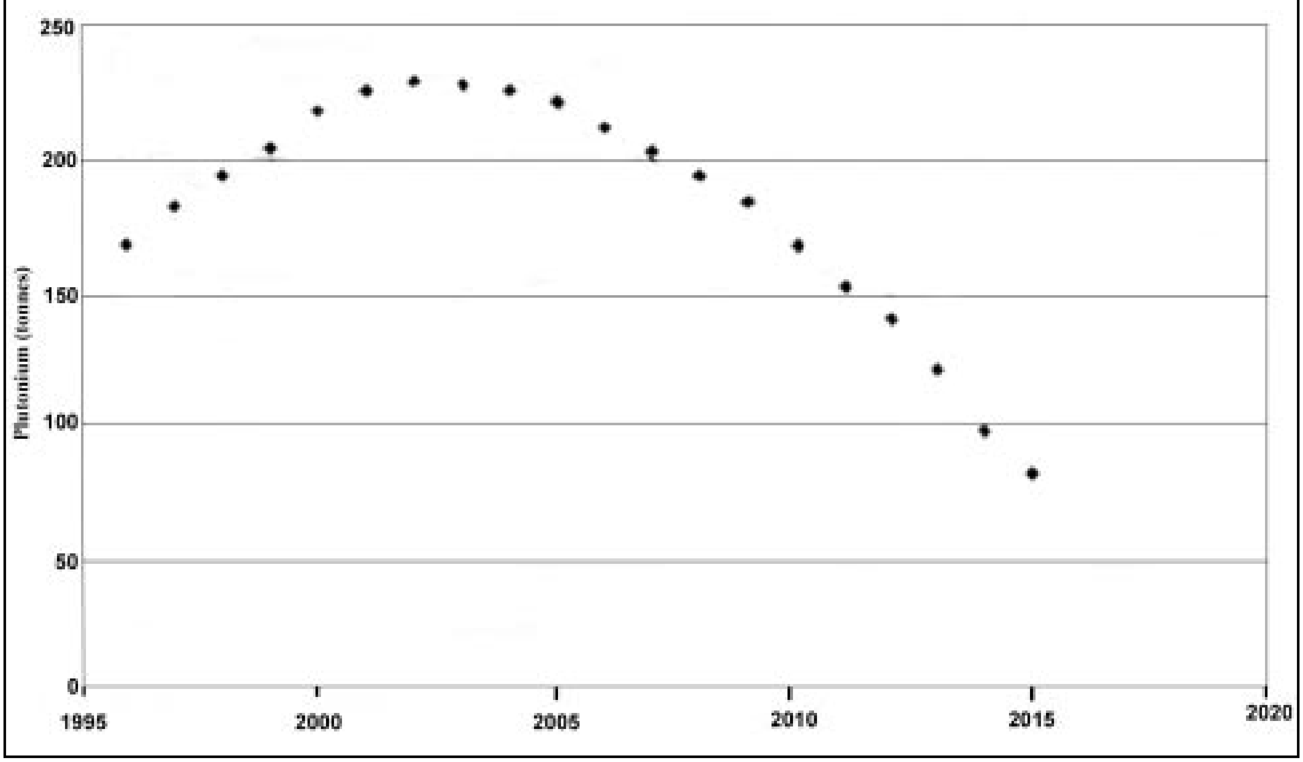


Figure 5: Estimated Global Civil Separated Plutonium Inventory,
Baseline Forecast but Assuming Melox reaches 250 tonnes per Year and UP2 and UP3 Close in 2010



Now, if you consider this problem more from a country perspective—if you start factoring in what reactors can burn MOX, how well they can actually get MOX fuel, and what are the uncertainties in the decision-making in the country—the situation starts to get quite complicated in several countries.

Figure 6 lists the group of countries that are actively using MOX. Some are in a pretty good position—Belgium, Sweden, and Switzerland. In particular, Belgium and Switzerland have been using MOX for many years, and one would reasonably expect them to reach a zero inventory by 2010.

Figure 6: Separated Civil Pu Inventories and Projected Inventories (in tonnes)
Part I: Countries with plans to use MOX fuel

	Separated Civil Pu Owned by a Country in 1998	Separated Civil Pu Owned by a Country in 2010	Separated Civil Pu Owned by a Country in 2015
Belgium	2.8	0	0
France	40.3	30 - 45	20 - 45
Germany	24	0 - 30	0 - 20
Japan	29.3	15 - 35	25 - 50
Sweden	0.83	0?	0
Switzerland	1	0	0
Total	**98.2**	**45 - 110**	**45 - 115**

For France, again it really depends on the fate of Melox, and how much of the Melox capacity is used to make foreign MOX. It could be that the French inventory could come down, or it could stay about the same.

Germany is a wide open question. Germany believes there is a problem—and Dr. Kersting will talk about this more tomorrow—in getting MOX fuel. It has enough reactors to burn MOX, and that's why it can reach zero theoretically, but at the same time it may not be able to, given that it is competing with other countries for MOX fabrication. Germany may have a very difficult time reducing its inventory, and that problem could continue well into the future. And in fact, Germany may have the problem that if it does phase out nuclear power on a more accelerated schedule rather than a gradual schedule, it could simply reach the point where it doesn't have any more licensed reactors left to burn MOX.

For Japan, the problem, where I assume the Rokkasho-mura reprocessing plant operates—there are more estimates in the paper where I consider the case where Rokkasho-mura doesn't operate—is Japan's trouble getting reactors licensed to burn MOX. So it has quite a relatively large inventory now, and it is going to have trouble bringing that inventory down. It's worsened when Rokkasho-mura starts operating in 2007. In this calculation, I assume that it can make the MOX—a plant would be built in Japan—but it won't have enough reactors to absorb all the plutonium they're producing, and that will drive their inventories higher. At the same time, Japan will be competing for MOX fabrication services overseas. It's very unlikely that they're going to be going to Britain any time soon, and so where are they going to go to if Melox stays at 100 tonnes a year? So again, Japan's fundamental problem is licensing reactors to use MOX fuel, but it is also going to be competing for MOX fabrication.

The group of countries in figure 7 on the next page are the ones that have no current plans or firm plans to use MOX fuel. One of the problems here, I'd like to point out, is Netherlands. Netherlands is likely to accumulate three tonnes of separated plutonium. I don't see them breaking their reprocessing contracts, but they're planning to shut down their last reactor in 2003. There's a political discussion in Netherlands about whether or not this reactor should continue to operate in order to burn MOX, but I'd guess that it's a small probability that the Netherlands will continue to operate that reactor. And so here you'll have a country that will have three tonnes of plutonium and nothing to do with it.

Figure 7: Separated Civil Pu Inventories and Projected Inventories (in tonnes)
Part II: Countries without firm plans to use MOX fuel

	Separated Civil Pu Owned by a Country in 1998	Separated Civil Pu Owned by a Country in 2010	Separated Civil Pu Owned by a Country in 2015
Britain	59.8	90	100
China	0	0	?
India	0.7	?	?
Italy	0.5	1.0 - 1.5	1.0 - 1.5
Netherlands	1.2	3.0	3.0
Spain	0?	1	1
Russia	30.3	35	35
Total	**92.5**	**130**	**140**

One of the things that shows up over and over again in these kinds of assessments is that it is OK to send spent fuel overseas to have it reprocessed, but there seems to be a *de facto* ban on burning plutonium in any reactors other than those you own. And so, while Dr. Chebeskov said this morning that Russia would like to sell some of its MOX to another country to burn, he mentioned that that's not going very well.

The estimates that I did based on the first methodology, represented in figures 4 and 5, assume in essence that France would burn a lot of the world's plutonium, because it is the only one that has enough reactors over a sustained period of time to make a dent into this plutonium inventory. That is unstated in those estimates, but in reality, that's what would take place.

In reality, France is unlikely to burn other countries' plutonium. That kind of *de facto* ban does therefore complicate efforts to relieve the global inventory of separated plutonium. I think some speakers will return to that tomorrow.

Figure 8: Separated Civil Pu Inventories and Projected Inventories (in tonnes)
Part III: Countries Planning to Dispose of Civil Pu with Excess Military Pu

	Separated Civil Pu Owned by a Country in 1998	Separated Civil Pu Owned by a Country in 2010	Separated Civil Pu Owned by a Country in 2015
United States	4-5	5	5
Total	**4-5**	**5**	**5**

To complete the picture, this is the U.S. case, where what we consider to be civil plutonium by origin is mixed in and dealt with the same way as excess military plutonium (figure 8).

The totals are given in figure 9. Again, I'm taking minimum and maximum estimates and averaging them, and the uncertainty represents the range of values. The trend is essentially upward over the next 15 years. So the situation isn't expected to improve if you look at the country-by-country assessment. There will be some exceptions, obviously, but on balance the separated plutonium inventory is expected to continue to go up. The second methodology varies very much from the first assessment which is basically assuming that if you get it into MOX you can use it.

Figure 9: Total Separated Civil Pu Estimates (in tonnes)

	End of 1998	2010	2015
Country-by-Country Estimate	195	210 +/- 35	225 +/- 35
Aggregate Projection	195	195	155

For lack of time, I think I'm going to skip the third methodology, which is actually fairly complicated. It has to do with estimating the probability that a country will burn up all its separated plutonium. Germany, again, is a good case, where the range is zero to 30 tonnes in 2010 and zero to 20 tonnes in 2015. There is a fairly decent probability, actually slightly over 50 percent, that by the year 2015, Germany will bring its inventory down to zero. Another way to describe the result is to contrast it with the second methodology, where Germany has a range of zero to 30 tonnes in 2010, but has no "most probable" outcome. The third methodology tries to put a distribution on that range that's more realistic and can predict more probable outcomes. But I'll spare you that, and just make a few quick observations.

First, if you look at these numbers, most of the plutonium is in the nuclear weapon states, but there are many non-nuclear weapons states that are going to have inventories for considerable amounts of time. One of the issues is whether or not they will repatriate their inventories, or will the inventories stay in the nuclear weapon states?

Second, in these analyses I see a reprocessing industry essentially in decline. The problem is not that it can't technically reprocess spent fuel, but this industry is lacking customers. That decline in the reprocessing of spent fuel is contributing to the decline in inventories in the first methodology.

Finally—and we will talk more about this during other parts of the conference—is the issue of MOX fabrication. There is a serious problem in that industry right now: Can the fabricators make enough MOX fuel and can it be loaded into reactors?

Let me stop there.

Kevin O'Neill: Thank you, David. If we're to stick to our schedule, we have time for just a few questions.

Q: David, you said your estimates of plutonium were subject to political uncertainty; could you give us some examples? Jor-Shan talked about the Chinese declaration of zero in the plutonium management guideline report; would that be one of them?

David Albright: No, these are different. I'm talking about political decisions, such as the cancellation of the Wackersdorf reprocessing plant in Germany in the 1980s. That would be fairly draconian political decision. Currently, there are decisions that are being made about whether or not the SMP—the British MOX plant with a capacity of 120 tonnes a year—should operate. So, for at a least a year, it's been undergoing cold-testing. Yet, the license probably isn't going to be granted in 2000, and some asked whether or not the plant will ever operate because of the recent scandal. These are the kind of decisions that I am talking about.

The other type of political decision is that it just takes a long time in certain countries to get a reactor licensed so it can burn MOX. This has been a particular problem in Japan. So, when you do the Japanese estimates, you're largely varying the time when a reactor will get a license. You're looking at the best case, which is essentially the industry plans, and you're doing variations based on. Maybe you're going to have a two-year delay, maybe a three-year, or four-year delay in getting the license.

Q: I want to comment made on an issue raised by Jor-Shan. You were mentioning local opposition by groups opposed to MOX in Japan. That barrier is not as great as you think. It is only one shot in the initial stage. Once this license is granted, the local governor has no right to override it on the additional cycles. The utilities are ready to stop the reactor and load the fuel. You're argument is, I think, very weak.

Kevin O'Neill: Thank you, I'm sorry we don't have time for more questions.