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Initial Core Effect on World Uranium Demand

It is truly exciting and an honor to speak to the Symposium today on the subject of initial cores that will fuel the next generation of reactors in support of the nuclear renaissance. To many of the more experienced people in this room, this full-fledged resurgence of nuclear power represents the realization of a dream that our industry does indeed play an integral role in the supply of clean, abundant, reliable and competitive electricity to an energy hungry world. To the vitally important, younger generation joining our industry, this development is an affirmation of a wise career choice and a bright future in a growing and exciting field.

Gone from the headlines are talk of early retirements of reactors and cheap abundant natural gas as the generation choice of the future. In their place has emerged a near worldwide embrace of our technology. Nuclear power is now seen as the best source of baseload power to the rapidly growing economies of India and China, the clean air choice in a world deeply troubled by global warming, and the economically competitive winner amongst the available alternatives in both regulated and unregulated environments. The extent of this renaissance has been well covered by other speakers this week so the purpose of my paper will be not to marvel at its coming, but rather to focus on one of the practical challenges our industry will face now that the renaissance is here.

In this nuclear rapid-growth scenario we are aware of the challenges of securing long lead-time items such as pressure vessels, vessel heads and steam generators. We understand the potential shortage of experienced engineers due to years of falling nuclear science enrollment in our universities, and the challenge of the regulators to manage the staggering volume of licensing activities. But what about fuel? Should we have concern regarding the ability of the uranium industry to respond to this very positive development — the nuclear renaissance? It would be the ultimate irony if fuel became an Achilles heel in the nuclear turnaround instead of one of nuclear power's greatest advantages.

It is not that market analyses (be it WNA's forecast or other commercial products) are ignoring the demand from new reactors. To the contrary, all these supply and demand forecasts take into account (to greater and lesser degrees depending on the level of optimism) the additional requirements coming from new build. WNA for example, in the reference case published in the market report one year ago, shows a relatively steady annual uranium demand growth rate of between 1% and 4% per year coming from improved plant operations and the addition of 105 new reactors in the period 2006 to 2020. Since the time the WNA market report was published, however, there have been many announcements, and the WNA website now shows that planned new reactors is as high as 232 (note this is not limited to the year 2020). Furthermore, these requirements models, generally assume that new units will require fuel two years before the unit enters commercial operation.

I wanted to challenge some of the standard assumptions about new reactor demand and dig a little deeper into this phenomenon that we will call the "initial core effect". The real question is whether this demand will occur in an orderly fashion, or due to a number of factors, will materialize much more in an irregular spike of demand. Moreover, it is interesting to speculate when this category of demand might peak and what will be the uranium industry's capability to respond in those years.

Initial Cores 101

First of all, it is useful to ask, what is an "initial core" and how does it differ from a reload? That may seem a little basic to those of us with either a little grey hair who remember the last wave of reactor construction, or those whom have been involved in more recent growth in Asia. However, for many in our industry, the prospect of nuclear growth is a new development, one that they may have not yet experienced in their careers. So let's start with the basics.

An initial core simply refers to the first loading of fuel into a newly constructed reactor which is embarking upon its first operating cycle.

A reload, of course, refers to the refueling of that reactor which occurs 12/18/24 months following the start of subsequent cycles. Core designers bear with me, but it is safe to say that reloadings in a light water reactor typically involve replacing a third to one-half of the core and reshuffling the remaining fuel to achieve optimal safety, economics and burn-up of the core in subsequent cycles.

So it is here that we debunk a common misperception regarding initial cores...

Logic would dictate that if a reload involves fuelling one-third of the core and the initial loading would involve fuelling the entire core, then an initial core should require three times more uranium than the reload. Not true. It has to do with the average enrichments being loaded. While the average

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General Electric - Economic Simplified Boiling Water Reactor (ESBWR)

Size:	1,500 MWe
Fuel type:	10x10 10 foot length
# of assemblies:	1,132
Average enrichment:	2.0 w%
Uranium feed requirements:	675,556 kgU as UF_6 (1.765 million pounds U_3O_8)
SWU requirements:	277,241 SWU

Westinghouse AP 1000

Size:	1,117 MWe
Fuel type:	17x17
# of assemblies:	157
Average enrichment:	3.4 w%
Uranium feed requirements:	636,000 kgU as UF_6 (1.662 million pounds U_3O_8)
SWU requirements:	353,000 SWU

Areva - European Pressurized Reactor (EPR)

Size:	1,600 MWe
Fuel type:	HTP 17x17
# of assemblies	241
Average enrichment:	2.66w%
Uranium feed requirements:	726,039 kgU as UF_6 (1.897 million pounds U_3O_8)
SWU requirements:	361,086 SWU

enrichment in a reload might be 5% in order to run long cycles and offset the remaining once and twice burned fuel in the core, initial cores might average 2.5% enrichment to achieve the appropriate neutronics of the first cycle where all the assemblies are fresh. Some designs, in BWR's for example, also use a great deal (perhaps as much as 25%) of natural uranium in assemblies at the periphery of the core as a blanket effect. Other designs may use axial gadolinium zoning and slightly enriched blankets. The objective is the same. Neutrons bombarding the pressure vessel, and not fissile U-235, are wasted neutrons. Enough of that "in-core fuel talk", this uranium salesman is straying too far from his comfort zone.

The net effect is that the uranium requirements of the initial core are not three times that of the reload, but closer to one and a half times. Having said that, most new reactor designs are quite large (as great as 1600 MWe for the Areva EPR). Let's look at three examples (all assume 0.30 tails assay).

It is important to note that while the uranium demand created by an initial core is one and a half times that of a reload, to the fuel fabricator, the demand on the UO2 conversion, pelletizing, tube fabrication and fuel assembly manufacturing is two to three times that of a reload.

This fact is central to one of the conclusions of this paper that while sufficient fuel manufacturing capacity might exist for new build fuel, the scheduling of this sizeable manufacturing commitment over and above existing fuel business will drive the lead-times for the delivery of EUP. Put another way, the scheduling of your initial core uranium (and SWU) requirements will be determined by the volume of business scheduled in the fab shop (that is both existing business and other initial cores - foreign and domestic). Overlaying this is also the assumption that for security of supply reasons, it is doubtful that nuclear fuel managers will rely on just-in-time delivery of the initial core on site. Rather they will want this fuel on site, out of the crates and in the pool, well in advance of the fuel load and start-up.

Analysis of initial core demand

So, what is the impact of all this new uranium demand, and what would this curve look like if we isolated it using some fairly general assumptions.

ASSUMPTIONS:

1. Commercial start-up dates were assumed for all announced new reactors by 2020. We constructed these timelines from published material and discussions with utilities and concluded that 168 reactors could reasonably be expected to start-up in this period (which is comparable to the current WNA data).

2. A generic initial core requirement was assumed for each of these new builds and uranium volumes were assigned accordingly. This generic core was determined to require 1.8 million pounds U3O8 (690 tonnes U) and was simply calculated by averaging of the uranium requirements of the Westinghouse, GE and Areva designs using a .30 tails assay assumption. While not the main focus of this paper,

in the supply and demand charts, I have included the follow-on reload demand for these new reactors using the assumption that the annual requirements will be similar to that of a large existing reactor (1.2 million pounds (460 tonnes U) per reload). As for Russian designed reactors, Candu units or smaller reactors (Pebble Bed), we used different assumptions based on their specific requirements.

3. Leadtimes were established for both on-site fuel delivery and delivery of EUP. For security of supply reasons, and to simply accommodate the core loading, the on-site fuel delivery was established as one year prior to commercial start-up. EUP lead-time (that is delivery of enriched product to the fabricator) was set at two years in advance of fuel delivery to accommodate the fab plant loadings and manufacturing schedules of the fuel fabricator. UF6 feed to the enricher was deemed to take place one year prior to the EUP delivery.

The net assumption is that the uranium demand will hit the market four years prior to the reactor start-up. As we will explain, in practice, this lead-time will in some cases be driven longer or shorter due to a variety of reasons and procurement preferences.

Regional Impact

Let's start by building up the initial core demand regionally.

UNITED STATES OF AMERICA

First, let's look at the US nuclear renaissance. As a result of economics, energy markets, clean air concerns, favorable politics, and warming public opinion, we are on the verge of the first new nuclear plant orders since the 70's. However, much of the groundwork is already underway in the form of pre-approved reactor designs, early site permitting and the combined Construction and Operating License activities being undertaken by a number of utilities and reactor vendors. For purposes of this analysis, we are assuming that 20 reactors will come on line in the US by the year 2020 (actually 21 units when you count TVA's advanced stage Browns Ferry 1). The earliest new units in this scenario will come on line in the 2014-2016 time frame. They are:

- NRG - South Texas 3 (GE ABWR)
- South Carolina Electric & Gas - V.C. Summer 2 (AP1000)
- Dominion - North Anna 3 - Virginia (ESBWR)
- Southern Nuclear - Vogtle 3 - Georgia (AP1000)
- Duke Power - Cherokee - South Carolina (AP1000)
- Progress Energy - Harris - North Carolina (AP1000)
- Entergy - Grand Gulf - Mississippi (ESBWR)
- Constellation Energy - NY or Maryland (US EPR)

The aggregate additional uranium demand for just the US market from these initial cores through 2020 is a substantial 43 million pounds U3O8 (16,540 tonnes U). The peak occurring in the years 2012 and 2013.

EUROPE

Despite challenging political conditions in some European countries, the region is expected to add 12 new units through 2020 for a total uranium requirement of 23 million pounds U3O8 (8,850 tonnes U). We are assuming this growth will come from new builds in France, UK, Czech Republic, Slovakia, Lithuania, Netherlands, and of course Finland who are in the construction phase at Olkiluoto and could conceivably add a fourth reactor there by 2020.

RUSSIA AND EASTERN EUROPE

Russia has announced ambitious plans for new Russian reactors, increasing nuclear generating capacity by 40 gigawatts by 2030. This will require the construction of two 1,000 megawatt reactors per year beginning as early as 2007, with a total of 18 new reactors in operation by 2020.

In Eastern Europe, we can assume at least another five new reactors in Bulgaria and the Ukraine.

Together, Russia and Eastern Europe may have initial core uranium requirements of 28 million pounds U3O8 (10,770 tonnes U).

ASIA (EX-CHINA)

Initial core demand in the traditional Asian market (Japan, South Korea, Taiwan) is materializing much sooner than in any other region with 19 reactors coming on line through 2015. Some of these projects have been long in coming, but will certainly have the jump on other new builds around the world due to their advanced stages of development. These earlier start-ups include:

Japan:

- Tomari 3 - Hokkaido
- Shimane 3 and Kaminoseki 1 - Chugoku
- Fukushima-Daiichi 7 and 8 and Higashidori B1 - Tepco
- Ohma 1 - EPDC
- Tsuruga 3 and 4 - JAPC

Korea:

- KHNP plans to have eight APWR's start-up by 2015.

Taiwan:

- Taipower continues to work towards completion of Lungmen 1 and 2 by 2009/2010.

The total regional contribution from these initial cores adds 30 million pounds U3O8 (11,540 tonnes U) of demand to the market through 2020.

CHINA

The prospects for new build in China as we all know are very exciting and well under way. With 10 reactors operable today, seven of which have been added in the last five years, the Chinese leadership is taking strong and unequivocable steps towards increasing its reliance on nuclear energy as a means to fuel it's remarkable economic growth in an environmentally acceptable manner. Based on this optimism and commitment, the assumption here is that China will add 36 plants to the grid by 2020 amounting to initial core demand of 41 million pounds U3O8 (15,770 tonnes U). China does have some domestic uranium mining operations (approximately 2 million pounds U3O8 annually (750 tonnes U)), however growth of this magnitude will require substantial imports of foreign uranium (a process which is also well under way - i.e. Kazakhstan, bilateral talks with Australia).

OTHER

This category captures all other nuclear growth around the world not addressed in the foregoing regions. The uranium demand from this group is not insignificant at 33 million pounds U3O8 (12,690 tonnes U). Examples through 2020 include:

India - Like China, India has made a priority of developing its nuclear capacity to meet the needs of its large population and growing economy. The nuclear cooperation initiatives with the United States, France and other western countries signals India's commitment to the peaceful uses of nuclear energy and hopes of ending its isolation with international participation in its growth plan. The assumption here is 24 new units by 2020, which will allow India to reach the stated target of 20,000 MWe.

Canada - We assume the addition of three Candu units in the Province of Ontario where the energy policy is refocusing on nuclear and away from fossil fuels.

Latin America - Steps are being taken for the construction and operation of Laguna Verde 3 in Mexico towards the end of the period. In Brazil, the start-up of Angra 3 appears fairly certain by 2011, with the completion of Atucha 2 in Argentina likely to follow.

South Africa - The most immediate plans are for the Koeberg 3 pebble bed. As many as nine - 200 MWe additional pebble bed units and one additional 1,000 MWe PWR are assumed to follow.

Also in this category would fall the new builds in Iran, Pakistan, Indonesia, Romania, Turkey and Vietnam (with some of these occurring at the tail end of the study).

Supply and Demand Overview

Let's look at the net effect of this demand. *Figure 1* shows the initial core demand by region. In total, initial cores are expected to require 198 million pounds (76,160 tonnes U) of uranium through 2020. What strikes me about this figure is the fact that a significant amount of demand is already in the market from reactors around the world that are in advanced stages of the new build process. The next big wave of demand is seen in the 2011 to 2016 period.

In *Figure 2*, we have added baseline demand from existing reactors and layered on the follow-on reload demand from the new reactors, which amounts to a substantial 655 million pounds U3O8 (251,940 tonnes U) through 2020. While it is

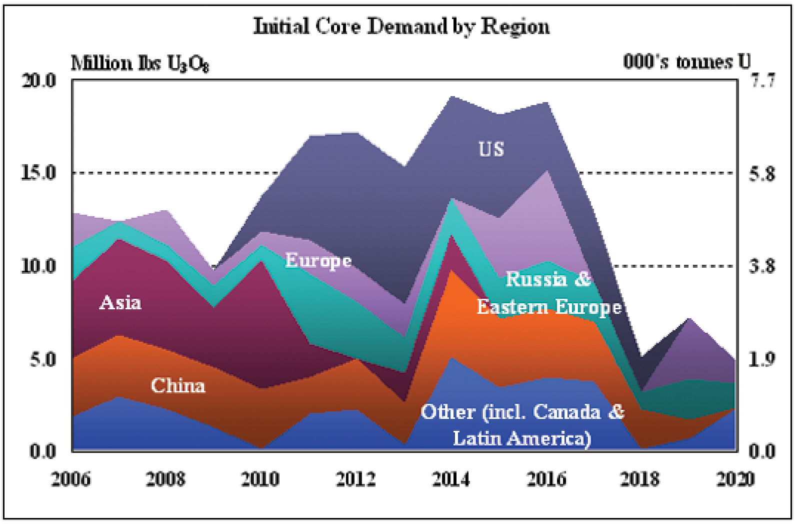

Figure 1

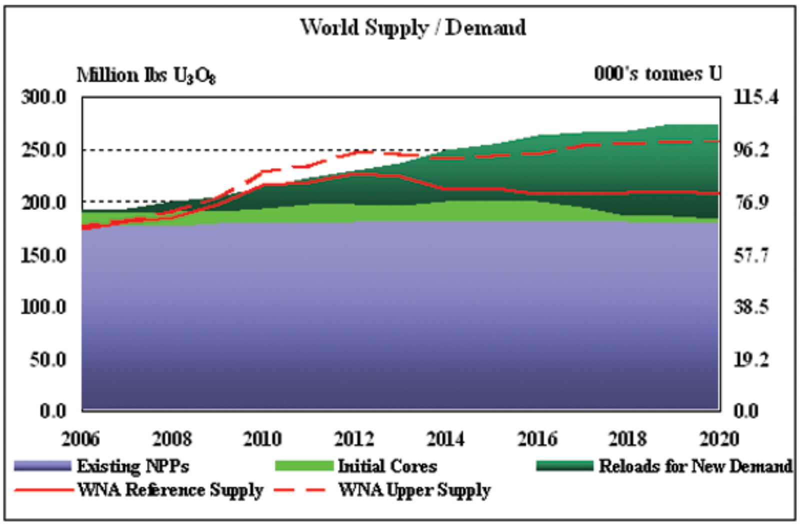

Figure 2

interesting to focus on the initial core effect of these reactors, one must not lose sight of the ongoing demands that these units will place on the uranium market going forward. This is the future that we as an industry need to get our heads around.

Lastly, we will overlay the WNA reference and upper uranium supply curve which demonstrates how the initial core effect has pulled uranium requirements forward such that demand exceeds supply through 2009 in both the reference and upper supply cases. This is in contrast to the WNA reference supply and demand case in the most recent market report where supply exceeds demand through 2015. Put another way, every bit of the WNA Upper Supply case will be needed (and then some) to support the magnitude of new nuclear growth being contemplated around the world today.

Conclusions

WHAT CAN WE CONCLUDE FROM ALL OF THIS?

1. Demand for uranium generated by this initial core effect may occur in an irregular fashion rather than a nice smooth gradual increase (essentially due to the first wave of new units scheduled to come on line in the 2015 time frame). The peak of this initial core demand will fall heavily in the 2011 to 2016 time period from currently planned and identified units.

2. Initial core uranium demand will materialize much sooner than many would expect. Fabricator lead-times, security of supply concerns, availability of uranium and simply the risk management desire to "lock down" fuel supplies for a $2.8 billion reactor investment will combine to push this demand forward. A number of new build utilities are already actively securing initial cores for units which are planned, but not yet firmly ordered.

3. There could be an "early mover" advantage on the fuel side of the new build decision. In the US, we are familiar with some of the other, more obvious, examples of early mover advantages that are included in President Bush's Energy Bill. They include loan guarantees, insurance against regulatory delay and production tax credits. Other incentives involve the desire to get on the regulator's agenda early with regards to license approvals and the practical step of getting one's major equipment, like pressure vessels, into the manufacturing queue.

   Might it also make sense to get onto the fuel fabricators manufacturing queue and have your fuel cycle components (feed and SWU) lined up before the bulk of the new build rush of demand hits? The data would certainly support this. Early movers will see the advantage of having their initial cores scheduled in "prime time". Late comers will see one of two developments. Either their fuel manufacturing will be advanced, pushing uranium demand into a very tight near-term market and significantly increasing carrying costs, or, will delay fuel deliveries, perhaps pushing up against start-up dates.

   Fabricators available capacity and scheduling of initial core fabrication will drive the timing and scheduling of EUP deliveries and may be somewhat out of utilities hands. Again, this pace of new orders may push this seemingly distant demand into the very near future (maybe now).

4. Security of supply concerns will also accelerate initial core demand. Lead times and inventories held by utilities have already increased for this existing fleets of plants. If utilities considering new build reactors are investigating fuel supply, even before a firm order is placed, there is firm evidence that no one will consciously plan to push initial core supply to a last minute decision. This factor will certainly play a role in new build reactors that require a great deal of external financing. Risk is mitigated when the lenders see a secured source of fuel for an initial core and follow-on reloads.

5. Licensing could be an issue. While I am not aware of a licensing requirement to have fuel secured in advance of a license submittal (as was the case in the 1970's), I can't help but think that as part of a thorough and complete license submittal, evidence of the initial fuel supply would be considered a positive feature.

WHAT CAN WE DO?

1. Put fuel supply onto the critical path of your new build decision.

   Some new build utilities have clearly recognized the critical path role of fuel in these massive complex projects and will be rewarded for their foresight. Yet with others we are seeing a "siloing" of new build activities within business development groups as a host of other important issues have taken priority. In these cases, Nuclear Fuel Managers have not been brought into the process when clearly the supply and demand fundamentals for uranium would indicate that early action would be the prudent course. This may be an internal matter within your companies, but I urge you to advance that dialog within your new build teams.

2. Clarify the fuel cycle responsibilities between reactor vendor and utility very early on.

   If your reactor vendor has made firm, identifiable commitments to supply EUP for an initial core and follow-on reloads as part of your reactor deal, that is a fantastic feature and should be afforded significant value in your evaluations. However, if the fuel supply is only a vague offer with little detail or is an option to supply on behalf of the vendor, all I can say is "beware".

With one obvious exception, I am not aware of reactor vendor ownership in primary uranium production assets. They will have no easier time than you going into the tight markets to subcontract for your uranium requirements. The Nuclear Fuel Manager will be much better off using their fuel cycle savvy and contracting relationships to source these EUP components directly. This would also free up the reactor vendor to focus on what they do best (besides, there is likely very little profit for the fabricator as an EUP middleman, only substantial risk). This doesn't mean that the fuel cycle players (uranium producers, converters, enrichers and fabricators) shouldn't coordinate their efforts or seek innovative solutions to help meet this challenge. We all have an enormous stake in assuring that the fuel side of the nuclear renaissance runs smoothly without dysfunction.

3. Continue to support the optimism and growth taking hold in the nuclear fuel cycle through contracting practices which encourage new production.

High prices may be uncomfortable to deal with in the near-term, but these are exactly the price signals that are required to stimulate the required capital investment of a growing industry. This is important not just for new build, but for the existing fleet as well. Uranium producers need to discover new deposits and bring on new production. Uranium converters are again talking of new plant investment. The enrichment industry is completely transforming itself from old to new technology. Fabricators and reactor designers finally see a market justifying their major commitments. Supply contracts which baseload these activities and hasten their development are in everyone's best interest (Cigar Lake and the National Enrichment Facility in New Mexico clearly moved forward on that basis). Remember, our supply and demand analysis concluded that every bit of the WNA Upper Supply scenario will be required (and then some) if we are to achieve the level of generating capacity our industry is currently promoting.

4. Procure initial core uranium requirements early and gradually over time.

No one said that an initial core had to be purchased all at once in one lump. Fuel Managers might find it prudent to accumulate those requirements over time, which might ease the market impact and will certainly be positive from a risk management perspective.

5. Recognize that Governments might play an important role turning potentially damaging uranium inventories into valuable initial core assets.

Yes, you heard me right; governments might have a unique role to play in a comprehensive plan to support initial core requirements. My hope, however, would be that this could be done with full recovery to the taxpayer and minimal impact to the commercial uranium markets. Take the United States for example. Much to the detriment of the domestic fuel cycle, excess US Government inventories - a bubble of supply - continue to overhang the market casting uncertainty upon commercial investment decisions. This paper has pointed to a potential bubble of demand created by a wave of initial core uranium requirements. Furthermore, it is reasonable to predict that the early wave of these requirements may come at a time when the commercial uranium market is still gearing up and not fully able to respond to this demand in a timely manner.

Why not match this bubble of potential supply with the bubble of initial core demand? This can be accomplished by the US Government making available sufficient quantities of uranium to supply the initial core for any US reactor which has submitted an application to the Nuclear Regulatory Commission for a combined Construction and Operating License (COL). This program could be limited to the first five to ten plants ordered to provide an early mover incentive. This kind of program can be a win-win for all parties:

- the US Treasury will be pleased by the fact these sales would be at then current market terms (not gifted), which would allow for full recovery to the taxpayer. Depending on the US Congress Appropriations process, these funds might also be directed back to the Department of Energy US new build/licensing financial obligations;
- the prize for uranium producers includes the fact that while the initial core business might be lost to government sales, they will have the opportunity to refuel these new reactors. Reactors which are constructed and started up on schedule in part because of US government support. Currently most suppliers are ill-equipped to meet this near-term demand anyway given current production and commitments so the program would ease undue pressure on the market;
- the utilities benefit from this responsible liquidation of government inventories as they gain a domestic source of supply from which to reduce their initial core supply risk; and
- in fact, we could say the entire nuclear industry would benefit from the situation described, as the US government programs aim to ensure new builds are completed and begin operating on time and on budget.

This is, of course, not a global or even a long-term fix. As large as government inventories are, the 168 plus new reactors expected worldwide will far outstrip those finite quantities and the commercial industry must assume the major share of the heavy lifting.

Closing

In closing, we as an industry can stop dreaming about the nuclear renaissance and should instead be taking all steps necessary to make it a reality. The challenges are still immense, however look at the positive signs:

- public opinion has returned to the support of clean, safe nuclear energy;
- government policy is again turning supportive of this competitive technology for solid economic, environmental and energy security reasons;
- nuclear engineering enrollment in universities has dramatically rebounded;
- major nuclear equipment suppliers are seeing strong signals to expand their business;
- reactor designs are being pre-certified;
- plants are being proposed and sited in supportive communities;
- environmentalists are touting nuclear's clean air benefits; and
- the economics of nuclear energy are evaluating favorably against other alternatives.

We, as the worldwide nuclear fuel industry, need to ensure that the fuel cycle is included in this list of positive drivers supporting the nuclear renaissance. I have only spoken of uranium today, but the supply of UF6 conversion and enrichment services to these new reactors will also be challenging in the near-term. I encourage the WNA membership to put the reliable, competitive and timely supply of initial cores on our list of priorities and explore what each of us can do to support the worldwide re-deployment of nuclear power to an energy hungry world.