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Transcript

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DESTINATION UNKNOWN: WHERE IS THE GLOBAL NUCLEAR FUEL CYCLE HEADING?

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MARK HIBBS: So it's about 4:00 right now and we can get started.

My name is Mark Hibbs; I'm from the Carnegie Endowment. I welcome you today to the panel discussion on the future of our nuclear fuel cycle.

I proposed that this panel be put on the agenda of the conference because we are in a situation where over a period of about 10 years, there is far more interest in nuclear power as a long-term energy fuel option. And we are now talking about a nuclear industry and a nuclear energy system, which is going to be with us for a long time. Should the promise held by nuclear energy turn out to be true, then as we move into the middle part of this century, we'll have to start to think seriously about the sustainability of the nuclear option in a way that we never did before.

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The United States, as is well known to most or all of you, has been very comfortable in having a nuclear fuel cycle which relied more or less exclusively on fresh uranium fuel. Other countries have taken a different route. They, beginning as early as half a century ago, developed a nuclear power plan that relied on plutonium fuels and fast reactors. Fifty years later, that promise has not been fulfilled; but the plans for breeders and plutonium fuels remain on the books of many countries.

That hasn't been challenged. We're still in a situation where the breeder planners and advocates are still holding forth. Important countries still anticipate having breeder programs and we're now in a situation where we're going to have to plan for a future that's going to have a – you know, a lot more nuclear reactors. There's going to be a lot more nuclear fuel that's going to be used and we want to discuss how the fuel cycle will go forward.

And so for today, I have three panelists who are very well known to everybody in this business. We have Phil Sewell on my right, who is the senior vice president of the American Centrifuge and for Russian HEU at USEC. The biography of Phil is in the program; you can read about it, but you know, it should be obvious to everybody why he's on the program.

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On my left we have Dr. Mujid Kazimi, who is at MIT and has been deeply involved in an important study which he's going to discuss here on the future of the nuclear fuel cycle.

And then on my far left is Steve Goldberg, who is special assistant to the director at Argonne National Laboratory, who has been working on these issues and brings to the discussion a unique biography because of his previous work in the U.S. government in the area of financing. And so we'll hear from Steve Goldberg about some of the financial and economic constraints involved in developing fuel cycle alternatives.

So without further ado, I'll turn the podium over to Phil and he will begin the discussion.

Phil, it's yours.

SEWELL: Thank you Mark for that introduction; and thank you to Carnegie for inviting me to speak today.

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My goal here today is just to give you a commercial perspective of the future of the nuclear fuel industry. And to start off with, there are a lot of countries that are involved in each phase in the nuclear fuel cycle. You can see them on this slide. And as you can see, the commercial nuclear fuel market by virtue of numbers alone is working well and is active and is looking to meet the future needs of the marketplace.

And all of the countries that are – all of the companies that are in these countries are supplying the market. And as such, they provide a robust and diverse supply in the international marketplace.

Now, the primary suppliers in these countries are constantly expanding, either through expansion of their existing facilities or deploying new technology – similar to USEC that is seeking to deploy a new technology. And as part of that effort of meeting the future demand, we're looking at a nuclear fuel cycle that's in transition in a number of ways, one of which is to transition to American Centrifuge. From 2010 to 2020, you'll see the transition where 90 percent of the enrichment capacity in the world will come from gas centrifuge.

Now, this transition is really predicated upon providing a modular technology that allows for the – that transition to replace – I'll say large-capacity, high-capital cost facilities and to modularly meet new demand. And to support this transition to a new capacity – 90 percent being from American Centrifuge – most suppliers are implementing long-term contracts. And they are doing that in order to assure funding to build that capacity, to expand that capacity and to match supply and demand.

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Now, going along with this future trend, all sectors of the fuel cycle, not just uranium enrichment, are undergoing transitions to meet demand. And the very basic fundamentals of this transition include the following: One, to assure that their transitions to meet the future demand are consistent with government policies and trends – both the existing policies and the evolving policies as the nuclear market evolves; and number two, to expand and finance these expansions on a risk-adjusted basis. And that's why you're looking at expansion in the – especially in a gas centrifuge on a modular – in modular increments in order to meet that demand and minimize the risk, so that that capacity is available and the demand is there that supports it.

In addition to that, this risk-adjusted basis involves long-term contracts with suppliers. In the enrichment industry, that's been an evolution from three-to-five year contracts to 10-to-15 year length contracts, in order to have the assurance that you can obtain the financing and the market is there support that financing to expand.

And with – along with this, we're seeing a transition where on a risk-adjusted basis the industry is looking at cooperation among companies, among countries to support the demand as it moves forward. In order to, I'll say, meet the demand, minimize the risk and to make sure that the financing is easily attainable by virtue of that, I'll say, ability to meet the demand. These partnerships look something like this: It's a – this will show you a little bit of the web of, I'll say, relationships between various companies that are joining together to not only minimize risks, but to provide a full range of services.

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Now, not all of these companies connect with each other, but if you'll just look at USEC: USEC has relationships with Toshiba, BMW, Rose Adam and the people that we have relationships with – either as investors or partners – also have relationships with others. Whether it be in Kazakhstan or industries in the United States like Westinghouse. And you can see – you can reach down from top to bottom so that you are looking at, I'll say, an evolution from singular industries and singular facilities where there is, I'll say, a partnership and a cooperation among a whole web – so to speak, in this computer world – of companies that are serving the marketplace and looking to minimize the risk while meeting demand.

So what demand are we talking about? OK. There we go.

This is a chart of the – showing that the expansion and the growth of nuclear power and the sources of WNA, the World Nuclear Association. But the point here is that existing markets have some plans for expansion, but nuclear power is going to see the largest growth in emerging markets. Now, that's a new dimension, that it – and in terms of that new dimension, it creates complications for both suppliers and government policymakers.

Now, governments and multilateral cooperation – there's policies involved in both of those venues that are supporting the international cooperation between companies and customers, as well as taking into account the role of emerging markets within the lifecycle management of nuclear fuel.

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These policies must match – the cooperation between the countries; the cooperations between the companies. What are some of the areas in which we're looking at in terms of cooperation? A positive trend in this respect has been an increase in those areas – the bilateral cooperation between countries and between companies with established industries and emerging markets.

One primary concern of all of these areas of cooperation focuses on enrichment and recycling as dual-use – as a dual-use path to weapons. And to balance the concerns of these new countries or emerging markets about supply – with the international community's concerns about proliferation – there is a need to implement supply assurances that reduce the need for indigenous capacity of enrichment for recycling at the facilities that have dual-use capabilities.

Now, if properly implemented, the assurances that existing governments and existing companies can provide, will remove the validity from emerging markets and of that argument that they need indigenous capacity to support a commercial nuclear power program. And in this regard, I should note that – that the fuel banks really only serve as a last resort or a short-term fix if the commercial market fails. And because of the size of these fuel banks, they are short-term solution only.

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So what type of cooperation is needed? What type of support is needed? Fuel banks are a good start, but we need the governments and the industry to work together to accomplish the goals of the increased use of nuclear power without proliferation risk. And going back in history and a continuing program – a best example of this government and industry cooperation that I can think of is the Megatons-to-Megawatts Program that USEC has been involved in, where purchases of down-blended, highly enriched uranium from dismantled nuclear weapons, has been ongoing since 1993. And this has been a cooperation between the Russian government, the U.S. government and private industry in the United States and a commercial entity in Russia.

Now, we recently announced a continuation of that cooperation between two companies in the United States and Russia, USEC and TENEX, involving a transitional supply arrangement, where we will continue, not with down-blended HEU but commercial material for the purposes of providing supply to the marketplace. But the major point there is that that is a foundation. Anytime you have cooperation between companies, between two countries or more, there is the capability to provide the framework to do additional nonproliferation work in the future. This has worked in the past and it can work in the future. And government and industry, we feel, needs to work together to make that happen.

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In terms of fuel cycle management, we can manage the entire path of the fuel from the start to finish in a manner that gives everybody the assurance that their priorities are being met – being met. You'll see here on this chart there's a three-layer mechanism, basically, of the fuel cycle management that would include: The commercial contract and supply of nuclear fuel – and maybe in a controversial way, to take back that used fuel, especially from emerging markets as a disincentive for deploying or utilizing indigenous capacity that has a dual-use capability.

And then as a second step, government level assurances are needed to ensure that the commercial contracts are honored and that facilities for used fuel – as an example – would be available either on a bilateral or multilateral basis.

And a third step in this process of managing fuel and this entire lifecycle, is arrangements to backstop – if potentially there is a disruption in supply – and that backstop being managed by independent third parties to provide the confidence that, indeed, it will be available if needed.

The big unknown in what I just said in terms of the future and where the global nuclear fuel market is headed – the fuel cycle is headed – is used fuel. The big question is what to do with the used fuel.

We can basically conclude that today, a decision point lies out there in the future that we all must face in some regard. That is whether to go down a path for expanded additional recycling or long-term storage or both. Both of those paths have significant cost and policy implications. So a key decision point is determining how one path or both paths can meet everyone's needs and priorities – in the context of those priorities; whether they be supply assurances, nonproliferation objectives, safety or long-term viability.

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In terms of storage of spent fuel, we know that we can safely manage used fuel at reactor sites or centralize interim storage locations for 50 to 100 years using current technologies. And there may be considerable value in implementing take-back arrangements for certain markets, in particular emerging markets, to improve the economies of nuclear power, meet their assurances of nuclear fuel supply and also satisfy nonproliferation objectives that we all have.

The future decisions – in terms of global nuclear fuel cycle: The centerpiece of those future decisions is used fuel and what to do with used fuel. So while we may not have to make that decision necessarily today, we do have to prepare for it because we know how we must address nonproliferation and economic objectives. Now the future formula involves government policies, industry support – then you'll see success in emerging markets. That's the centerpiece of where the global nuclear fuel cycle is headed. And so the commercial industry is ready and prepared to meet these objectives with our government counterparts. And only by working together – similar to how we did in the Megatons-to-Megawatts Program – can we support nuclear power's growth while also supporting nonproliferation.

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Here are the drivers – some closing comments. If emerging markets decide to implement nuclear power to generate electricity, commercial fuel industry must be ready to meet that demand. And if government policies are not established early in that process as demand evolves, then ensuring dual-use technologies do not proliferate are going to be difficult. And therefore, we need prompt government action and cooperation with the commercial nuclear industry. And without that, the future is going to be more difficult to shape, direct, to predict.

So bottom line here is there's two paths for the global nuclear fuel cycle in the future. It centers around used fuel. The decision by commercial companies in terms of cooperation and partnerships and governments in terms of their policies is going to shape that future.

Thank you very much.

HIBBS: Thank you, Phil. (Applause.)

The next speaker is Mujid Kazimi, and he'll – if I anticipate – his remarks will be taking a view from perhaps a little higher up in the atmosphere. (Laughter.)

[00:19:19:56]

KAZIMI: Well, I think Phil asked the question which is fundamental in the long term: Do we store the spent fuel for a long time or do we have to rush to do something with it? And my remarks will essentially try to point out all the factors that enter the equation, which might lead to selection of the better path forward. So the horizon that I'm looking at is something in the order of a century. And that turns out to be not a very long time when it comes to selecting the fuel cycle. As you will see, fuel cycle transitions take a long time.

But let me start by saying, what do we want our fuel cycle to do? Or in other words, what do we like in a fuel cycle? Well, we'd like the fuel cycle to be economic. And we know that the light water, once-through, fresh fuel is today the most economic. And it is hard, therefore, to displace it in the market without some policy interventions. We would like to have a sufficient amount of fuel so that when we build those expensive machines that are going to run for 60 years or more would be able to meet their need in the fuel market. And looking at the assessments for uranium fuel, there is enough, we think, at reasonable prices, at reasonable rates of growth in nuclear power to last a century.

But obviously, if we reprocess and we start using the produced fissile materials from the reactors in a recycling mode, that will increase the fuel resources tremendously.

We'd like to have a minimum waste burden. And here, when we look at what we have in the once-through cycle of today, we take the spent fuel and we place it in storage. We have very little treatment of it; the process is relatively simple. If we're going to go and reprocess it to extract fissile material and get the other benefits from that, it's going to create a lot of waste. And depending on how many brands of waste do we – or extractions do we want, there could be more ways than we start with. Therefore, it's a mixed bag here as to which cycle eventually, you know, will give us what we want.

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And lastly, the proliferation resistance: Again, here we have a question of, you know, if you don't touch the fuel, its contents are safe. If we start reprocessing then we have opportunities for diversion and copying that kind of technology, et cetera, et cetera. So in the short term, introducing recycling may not be as desirable from proliferation point of view. In the long term, if we don't extract the plutonium from what we sent down to a repository, it will start becoming like a plutonium mine and we need to be careful in the long term about protecting that material.

So with these thoughts, let me describe to you a study that we did at MIT in the last three years – and some of you may heard about it because we released a summary back in September and a full report should be ready in early April. To remind you, you know, of the – as long as the increase in demand for nuclear energy is moderate, we can meet that demand using uranium from mines. And the historical trends show us that, you know, as we need more uranium we're able to find it, because usually the price goes up, and when the price goes up, people start looking for it and they will find it. And you know, the IAEA data shows that our assured reserves have gone on by a factor of two over the last 20 years while we are consuming uranium.

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The other thing that you should note, is that in the very long term, we know that we're not going to be able just to rely on that uranium. We have to, therefore, recycle and create new fuel. So the real question in this fuel cycle is when do we need to introduce the recycling option? And that is the issue that we have to deal with. And it turns out to be affected by many factors, not always obvious at the outset. There are two reactors in our technology – (chuckles) – all right, here we are.

There are two types of reactors. The reactor of today which we call a thermal reactor consumes fissile materials more than it produces. But if we switch to a different kind of reactor called a fast reactor, we might be able to have more fuel than we consume. And that's the essence of that benefit of recycling in fast reactors. If we recycle in thermal reactors alone, we don't get that multiplication factor that we need. So we need a new type of reactor to come in.

Now traditionally, the assumed scenario is that we're going to take the fissile material – that means the plutonium and other – perhaps actinides – and take them from the spent fuel of light-water reactor in order to initiate the fast reactor when we need it.

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It turns out that if we're going to do that, we're going to have to accumulate many, many years of operations, because the need for one fast reactor will require operation of a light-water reactor of the same power capacity for about 35 years. So we will – we're very dependent in this transition on how much we have accumulated already and whether we can catch up – although we will be recycling in the fast reactors, fast reactors usually have a small increase in the value of the fissile material that they produce, which would help, but is not sufficient to derail this dependence on light-water reactors.

One thing we care about is the cumulative demand for uranium and the various options for the fuel cycle. Here we compare the needs of uranium in the United States if we depend on the once-through light-water reactor – that's the top row – with four other options. The second row is recycling the plutonium in light-water reactors, which will save us maybe 10 percent or so of the uranium by the end of the century; or recycling in fast reactors with different conversion ratios. The ratio of the fissile material that we end up with at the end of the cycle compared to at the beginning is called the conversion ratio, and we find like – we can build those fast reactors with anywhere between 0.5 conversion ratio to about 1.25.

So if we use this range, we find that there is an added value in terms of reduction in demand for uranium. But at most, this reduction by the end of the century is 30 percent. This is at most, and we – although these numbers are for a growth rate on the order of 2.5 percent per year in demand for nuclear energy, we've looked at 1 percent; we've looked at 4 percent; and the picture doesn't change. So there is some help to the demand for uranium, but at least in the first 50 years after the introduction of the fast reactor, it will be of limited impact.

We noticed that the share of light-water reactors in the total nuclear energy system in the United States would be dominant. That's light-water reactors. If we look at the once-through cycle – this would be that black line on top – that would be if we didn't have any other technology. But if we introduce the fast reactors, we will be building fast reactors as we go along. And the best one, of course, from that point of view is the breeding fast reactor with a conversion ratio of 1.23 – shown as orange in this slide at the very bottom. But it's not very different in terms of its impact on total capacity that we can build than, for example, having a conversion ratio of one. And that turns out to be an important conclusion in our study. I will visit it in a second.

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If we look at the transuranic content in the entire system – not just in storage or in reactors but the entire system – it turns out that the transuranic system, if we use a breeding reactor, that TRU would be more in the total system than just in the once-through. You see the orange has come above the black in this slide. With the consuming reactors, it is less than that. And of course, this is not to say we're going to be sending all this through in a – you know, in a haphazard way through repositories or some other way. In fact, we're using it to power the fast reactors.

But the issue is, if we ever discover a source of energy which leads us to divert our needs to that sort of energy because of, you know, something attractive. Solar energy becomes much more efficient in terms of conversion and what have you. Fusion comes around. Then we will have all that transuranics primitive material to deal with. And then we don't see a very big difference between the various cycles.

There is a difference in where the transuranics accumulate. The transuranics accumulate in the storage pools as well as in the cores of the fast reactors, as opposed to in the dry storage – interim storage that we know about today, where we have the spent fuel waiting usually in either pools or dry casks until it has an eventual place to go to. So it is a more active TRU in that it's being always used and processed, but nevertheless, it is a large volume – just almost as large as it is in today's system.

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There will be much less transuranics going to the repository, and that's one value that we should keep in mind. The introduction of a recycling fast reactor may reduce the total transuranic inventory in the repository by two orders of magnitude. Depending on how meticulous is the industrial process of recovering of the transuranics or – and manufacturing of the fuel from it.

So in total, the conclusion is from this study, that we do have a light-water reactor technology with us for at least a century; and therefore, it deserves to be enhanced in terms of its capabilities and such investments will pay off over the operation time of the reactors. In previous years, a national effort has gone into development of alternative reactors. Only recently, within the last couple of years, did the government start allocating funds for research for enhanced performance of light-water reactors.

The other conclusion is that we should probably prefer to have a fast reactor with just about even production and destruction of fissile material. A conversion ratio of one turns out to be just as a good performer for introduction of fast reactors into the system at a relatively good rate. And also, it has with it the ability to allow us to choose different technologies than the one that we have been assuming that we should use, which is the sodium-cooled fast reactor. We can use the light-water reactor to perform that way, or some other coolants as well.

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And we know the light-water reactor technology – in my opinion, with the industrial capacity that we have today to supply the needs of light water reactors – perhaps that is worth looking at very carefully.

We should also look at the possibility of introduction of the fast sodium-cooled reactor – if that's the choice – with uranium rather than plutonium as the initial fuel. We will have to – we will have eventually to recycle what's being produced in fissile material in the core. But dissociating the introduction of fast reactors from the need for plutonium inventories ahead of time make it much more possible for us to feel more secure about making the decision to get into reprocessing when it makes sense. And it will make sense when we will depend on fast reactors for the production of energy in a big way, and that may not happen until the second half of this century.

Thank you. (Applause.)

HIBBS: Thanks very much for that and now to the third speaker, Steve Goldberg.

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GOLDBERG: There we go. Good afternoon. I think the timing for my talk is – I'm between you and the – I'm between you guys and the cocktail hour, so I will try to be as expedient as possible.

Thank you, Carnegie, for inviting all three of us to this nice, very good session. I'm coming here to speak representing my work with the – supporting the Global Nuclear Initiative, which is supported by the American Academy of Arts and Sciences. And I'm working in collaboration with Dr. Bob Rosner at the University of Chicago and the project is co-directed by Scott Sagan and Steve Miller.

There are a couple of things I want to point out at the beginning of this: The question, where is the global nuclear fuel cycle heading? It's kind of a play on words, because global has some similarity or simile to we've got some idea how global thinking works here. And I tend to think we're not at that stage and I think Phil's pointed that out to some degree in his talk. We're somewhat bifurcated and trifurcated into various systems around the world and we're not at a point where we can see a unified approach.

The second point, the first part of the question, destination unknown. I think we know where we are, but as Professor Kazimi has kind of pointed out, maybe in a century from now we will be surprised where we're going to end up. So this – so there's a little bit of, you know, mapping this out and you'll see that a bit in my talk as we go forward here. So it is clear going forward that we're going to be needing a large fuel cycle if we see what the plans are for countries such as China and India. And if China and India, similar to Korea, get into the supplier process of new reactor sales, it is very likely we will have a large growth in the fuel cycle. And we're going to see large amount of spent fuel or used fuel created from this process.

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The other trend that is apparently coming into vogue is bundled reactor sales. And we're – the country – emerging country decides to order a plant, they would like to know what their fuel supply situation is up front. And if they're doing financing they would probably want it – to do a package deal with fuel as well as the reactor. So it's very likely we're going to see this bundled service approach. Now, it does beg the question on the backend, what happens? And in some cases we probably see countries like EDF in France, come with a service for reprocessing with the understanding that the waste would be returned to the home country.

Now, there's been a lot of discussion on various approaches as we move forward. And the former IEA director-general charted out a three-stage process. It is a very, very laudable process, but I don't think we're there even close to where this is going.

First step, which has been discussed by Phil, is this idea of a backup fuel supply or fuel bank. And this gives countries that are worried about a fuel supply cutoff the assurance of a supply of fuel for their nuclear reactors.

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The second step would be a signing any enrichment and reprocessing activities under multilateral control. It's been under a lot of discussion; there's been many agency meetings on this subject and it has been a wide discussion topic across – in the United States as well.

And of course, the third approach – once we could – might get there – might be an idea or concept called multilateralism to the full degree, which would mean all enrichment and reprocessing facilities under multinational operations.

Now, when you put that to where you might want to be in the future, you now look at where we are. And let's see – where we are is a consensus at the present time that the goal might – would be not to disturb the international market. There is a very viable international market for fuel services. USEC that Phil represents is one of the companies that works in this economy and there are already existing relationships between reactor operators and suppliers and the fuel cycle providers.

The second point that is clearly consensus is that if we approach a multilateral process, it should be done on a step-by-step basis. And in that way, you're able to make determinations of how well you're doing in the process before you move quickly ahead.

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The third – the third point is there's no one approach. There's no place in the cookbook you can go that would satisfy all technologies, all countries. And if we're going to be successful in any kind of a multilateralism, we would need to have flexibility on its application, which means that there are a variety of ways that countries could make relationships between the fuel suppliers and the fuel users and come out with a robust system.

In entering into these discussions, we end up with I think the five major topics. They normally come up in this process. The first one that Professor Kazimi discussed is the uranium – what is the situation with uranium? Is it going to be scarce; is it going to be expensive? And I think what Professor Kazimi said – and I agree with – is that at what price? And you'll find uranium probably – and it's more and more of it coming into play as we go forward. And there is the opportunity of going into the seawater to find uranium. So the uranium may not be a showstopper in this process.

The second point has to do with this balancing act between recycle and once through. And the key – two key questions come up in this issue of economics on the second point. One is how much is disposal really going to cost? And that is an open question. And where several countries around the world have gone down this road a bit, we in the United States did and now we're reassessing ourselves. And there've been, for example, in the United States total system lifecycle cost estimates. But those are dated, so we don't really know yet what the full cost of disposal is.

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The second point – and again, Professor Kuzimi alluded to it – is the issue of can we make a difference on the load in the repository with recycle? In our laboratory, we have done a lot of work in that area through our work with the Advanced Fuel Cycle Initiative. And it's very likely on the second point we're going to need a technology game changer, because to make this an economic, viable, highly secure process is clearly something that – which we have in the laboratory we've got to get into practice.

The third point is the balancing act of unused or spare reprocessing capacity. And it's probably likely now today we have enough capacity, but going forward, if the amount of used or spent fuel rises to the neighborhood of 400,000 metric tons to generate, it's going to be a really taxing process on that part of the back end of the fuel cycle. So there may be going forward a further bottleneck than exists today.

The fourth point is – let's see – here we go: Is whether the – the economics is the key discriminator in decisions on the front and back end. And the question revolves around the – the load that that has on the whole fuel-cycle cost and that fuel-cycle cost relative to the cost of electricity. And we have done studies – I've been involved with studies on this issue and you get different views.

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I mean, the view from the end users on the mils per kilowatt hour basis – it is not a big deal. But if you are making decisions that you're trying to be economic on how the fuel is going to be disposed of or processed and you have to decide if you're going to invest in new technology or a new plant, then it is a very important issue and you've got to have some sort of a payback process.

The last point that is raised by the – by the community is if one country or a series of countries decide to go on their own and do reprocessing and enrichment, does that have an impact on the rest of the world? And I think there are people who believe that it does, that there are precedents that are set. So if there are people who go off on their own doing these things, it is – it is likely to be a negative on the world stage.

So with these in mind, it is clear that – that the – that there are two key points that need to be done with respect to going forward in multilateral services. One is the issue of where we are on disposal. And there's a great quote that the Swedish – the country of Sweden put together in their working paper where they stated that it's – to be a practical process, we're going to have to figure out from public opinion how disposal is going to be cited in any particular area – whether we go into a regional or an international process.

The second one – and it's the one that I alluded to earlier – is there a competitive economic advantage going to a multinational approach over an indigenous development, enrichment and reprocessing?

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And going forward – and this is what we're doing in my work at the academy – it is important we promote a dialogue, because these questions, these issues require discussion with the major partners and stakeholders in the process. And one needs to think about what are the advantages and disadvantages of going with a process which has an international motif to it? And what are the gains we got from looking at countries that have been successful, such as Sweden and Finland; and areas where we haven't been as successful?

Now, there are clear items that as you start the dialogue where multilateral fuel assurance arrangements would be very productive. And we and myself have put together some flow modeling in this regard. And it is clear that if you got into a multilateral process for an emerging country, you would be able to see a robust approach to financial and institutional support for that program. You'd begin to see the opportunity that you would not have the risk – that you would not continue the risk of a supply cutoff. In other words, you would be able to maintain a set of diversification in your supply options and this would be able to manage risk going forward.

And the third – and I think most important issue that really gets into multilateral processes – is that when you are working with a developed – with a developing country and they're using the reactor sales as a pledge on the fuel arrangements, this allows for a very robust approach to be able to get back the financing that you need for a multilateral arrangement. And if a small country tried to do this on their own, it would probably lend itself to higher rates than they would otherwise, because of their issues involving a small country and a large investment.

[00:50:07]

On the other side of the coin, the negatives of going multilateral is the time. It takes a lot of time and requires a number of difficult and complicated arrangements around the institutional entities. It also would require – if we strung together a number of countries' needs for a multilateral approach – a lot of startup capital. And capital in most cases is very dear. And we heard earlier today in one of the presentations given with respect to the – what happened in Japan, that capital formation requirements – unless the host country is very directly involved in the process – is not an easy process.

And the third point is it's going to lead to protracted discussions. We're already seeing that a lot in the current format, ironing out contract and payment terms that likely take very long to implement. And it's difficult to see this as a very, very near-term options for this. But it couldn't – it could happen over a period of time.

Now, going into three issues where it looks – it could break in favor of a multilateral approach, but needs to be worked, is economies of scale. How big a scale of a process do you want to build? How will the advanced R&D concepts be supported in this approach and where would they be able to be injected into the marketplace? And finally – going back to what we said earlier at the beginning of this discussion, and really, the key point that has to be made again is the disposition of the waste.

So I'm going to kind of wrap up with issues that you all may be thinking of as you question the three of us here at the panel is what is – what is the competition today? What are the alternatives of going into a multilateral approach? How would it affect competition going forward?

[00:52:14]

If we put in all-in cost and we're thinking about avoided all-in costs – but particularly if you do not have to site additional repositories – is this a decisive ingredient into the conversation?

A third point is the regulatory issues. What are – what's the status of export-import licenses, retransfer of rights – how would that play out in a multilateral approach?

How could you go forward and still encourage participation by fuel-service providers, because at the end of the day, the fuel-service providers have to be there – such as Phil's company at USEC. They still have to provide the service.

What is the appropriate linkage between the fuel-supply network and the reactor suppliers? In other words, these large reactor suppliers who are out there – how are they going to interrelated in the process?

Going long term into the – to the end of the century, is there a long-term sustainability issue? Will we end up with a finite fissile supply – fuel supply leading the requirement to close the fuel cycle?

Going forward with four other points: Can we build off the current bilateral and multilateral approaches that exist in enrichment, such as the IUEC partnership that has occurred with Russia and Kazakhstan? Do we need a dedicated funding source and management entity to do any kind of a fuel waste arrangement? Is there – and this is something I used to do a lot at the Office of Management and Budget: Do we need federal or U.S. assistance in the process?

[00:53:58]

And next to last: Should we be thinking of flexibility – back to the point I made earlier in the conversation – between centralized or interim storage or regional storage and having the ability to be able to – to be able to work with both concepts? And are there advanced technology disposition pathways that could be brought into the process, such as actinide burning.

And finally and most importantly: Is this an economically viable process in the overall marketplace and what are the business principles? And I'm going to return to something that Phil artfully talked about and that's the HEU agreement. In my mind, the HEU agreement is one of the best examples of how a commercial agreement was implemented and was able to be done in a budget-neutral way and has been a very good approach to getting uranium out of weapons and used in the commercial approach.

Thank you very much for your attention. (Applause.)

HIBBS: Thanks very much, Steve.

And thanks to all three of you for these presentations. They are very illuminating and give us an opportunity to begin a discussion about this.

[00:55:13]

I'm going to take the chair's prerogative and ask a couple of questions before throwing it open to the audience. I will call on people who raise their hands. They will then be approached by somebody with a microphone. And when you ask your question, please identify yourself before you speak.

I've listened to this carefully, and I'd like to kind of bring this down a little bit into the real world of commercial enterprises and companies that are in the business of generating electricity. I heard you this morning listening to my colleague on the podium – Irv Rotter, a lawyer who works for companies that are in this business – and he talked about the lack of support on Wall Street for new nuclear construction in the United States.

And in the area of nuclear power, we can't seem to get the nuclear renaissance kick started in the United States in any fundamental way. It isn't moving on. Irv raised the specter that we might not have any reactors at all for maybe seven years or 10 years. And if you look at the nuclear fuel cycle, we're talking about moving into an area where investments will be needed in new technologies which aren't even going to be generating money. There's going to be risk associated with untried nuclear fuel cycle technologies. The nuclear fuel cycles advanced technologies will be perceived as adding cost to the process of generating nuclear electricity in a sustainable way.

[00:57:17]

And I would like to hear from both Professor Kazimi and from Steve Goldberg about how the nuclear generating world is going to get over this dilemma.

KAZIMI: OK. Let me start.

There is no question that nuclear power plants are rather expensive. And therefore, you need the capacity to be able to finance them. And very often – particularly in the United States – that takes more than one company getting together to do that.

On the other hand, once they are operating, they are very inexpensive to operate. And today, if you look at the generating cost – that is once you have written off the planned cost – nuclear is the least-cost-generating capacity in the United States – even with natural gas at the low prices that we have seen in the last month or two.

So if we are amortizing the cost over 15 years, because of the needs of the markets, the plans would look very expensive up front. But if we are looking – taking a bigger look – perhaps like in France where they can amortize it over the whole lifetime – it would look very different in terms of economics. So that's the first point.

[00:58:58]

But second point is, you know, in 2005 we had a law passed that said we need to support the introduction of new clean technologies. And so far, it has had very little real implementation. Only one plan received some degree of assurance that the government is ready to support the introduction of a new plant.

Why is this important? Because to get Wall Street to be confident that the nuclear new plants are going to be able to be built quickly and reliably will depend on the performance of these early plans. So if there was a demonstration of a couple of plants from the various designs, that will reflect on how much risk the financing institutions will ascribe to nuclear plants. So this is upfront with regards to the plants.

What was the second question? You had two parts, I think.

HIBBS: No. That's basically it.

KAZIMI: All right. I'll leave it to Steve.

HIBBS: Yeah. Steve, why should Wall Street finance the development of a new commercial fuel cycle?

[01:00:21]

GOLDBERG: OK. Actually, I have a good answer, because it sounds like a difficult answer. I think we have a track record, a little bit, that makes me more – I have a stronger view that fuel cycle services – particular front-end fuel cycle services – have a better play in the marketplace than the reactors in the United States. And let me give you a reason for why I think this way.

In the case of reactors – and Professor Kazimi is correct – that front-end investment side is the big hurdle. It's a huge hurdle. And only we have currently in the United States the project in Georgia – Plant Vogtle – that has gone through the loan guarantee program.

And clearly, the investment community – they use a term called the weighted average cost of capital. And it's with and without loan guarantees. And if you do it without the loan guarantees, these weighted average costs of capital are expensive. So if you go to a merchant plant market, it's difficult to see a nuclear plant going head to head with natural gas. Regulated market, a little bit easier, but clearly with loan guarantees still easier still.

In the case of the fuel cycle – and we have one example of that went through at the loan guarantee office in the United States, Eagle Rock; and there's another one, hopefully coming soon, with ACP – there is a more defined marketplace; there is an easier approach you can see when you put in front-end fuel cycle services. You have a customer base. You know what the customer demand's going to look like; you know kind of what the price is going to look like. You can do some calculations.

[01:02:05]

These facilities are regulated not as kind of in the more complicated reactor arena, which is still being – we're still working it in part 52. It's a – the fuel facility is a more direct, less complicated process. So when you look at weighted average cost of capital, when the loan guarantees come in, it's a much more direct approach. So on the front-end services, it looks OK.

Things get a little dicier on the back end. The back end is difficult. And the reason the back end is difficult – and as someone – I have been very much involved with in my previous life when I was at the Office of Management and Budget – we had to do what are called fee adequacy calculations. And you had to think about what the cost of the future's going to be and what fees are coming in and make adjustments appropriately.

And if the federal government or a government across the world is involved in this process, you've got to allow for processes that go on, because you're not sure at the end of the day what it's going to look like in the framework for disposal. So back to Mark's point – I'm going to kind of wrap it up into three points: Yes, reactors are difficult to finance. Front-end fuel cycle service is not so difficult; back end, dicey.

HIBBS: Thanks, Steve.

Phil Sewell, I have two questions for you. The first: I'd like to hear what you have to say regarding a view which is current in parts of the United States. The nonproliferation community and parts of the nuclear community in the larger sense, the view is expressed that looking at the supply of uranium in the world, there are people who are critical of recycling in a plutonium fuel cycle who support their argument by making the assertion that as long as the price of uranium incrementally increases, we're going to inevitably find more and more uranium and so there's no need to recycle. The stream of uranium – the flow of fresh uranium into the – into the nuclear market will indefinitely continue as long as the price incrementally increases.

[01:04:31]

And you know, some of these are friends of mind who will also argue that, you know, there's an infinite amount of uranium to be mined from the seawater. We don't need recycling. The uranium is all over the place; it's very available.

Phil, would you subscribe to that view or do you think at some point there's going to be a time when the demand for nuclear electricity and reactor construction reaches the point where, at some point in coming decades, we're not necessarily going to run out of uranium, but where the penalty imposed on a nuclear generator by the price of uranium would be so considerable that they would have to consider recycling?

SEWELL: Does anybody have an answer out there? (Laughter.) Oh, well, let me give you the microphone.

The supply of uranium is abundant, as long as it's economic to produce it. The issue is not the total supply of uranium in terms of its volume. As – I'll give an example – out of seawater: The issue is going to be economics of extracting that uranium. So there will be a point, and I don't know how long it will be – it may be 100 years – I honestly don't know where the economics may balance with respect to the economics of recycling.

[01:06:12]

A factor that people don't think about often is when you think about the lifecycle costs of nuclear fuel, you have to take into account the storage or the disposition of used fuel. And as we all know, recycling of used fuel reduces the volume of waste that you have to dispose of. And so at some point in time, there would be a breakeven or a crossover with respect to the cost of uranium as it fits into the entire formula of uranium, conversation, enrichment, fuel fabrication and – recycling and disposition. And recycling and disposition, today, is a relatively expensive proposition.

But there will also be the issue, as I mentioned during the talk, about what to do with used fuel and what to do with used fuel when it's – and particularly emerging markets that may have an interest in developing indigenous enrichment or recycling capability.

So therefore, from a policy perspective of the governments that really want to preserve a nonproliferation regime that is safe and secure, will look at the possibility of what to do with the spent fuel – either interim, long-term storage of the used fuel itself; or combining that with respect to recycling and using the existing recycling capability that I believe my fellow panelists pointed out that that's there.

I'm not sure exactly whether people will move away from uranium to recycling and take that into consideration today. I think the answer is no, because there is significant amount of uranium – the cost to extract it, compared to the market price is attractive. The cost of recycling is relatively costly. But both policy considerations and economic considerations, as you run out of low-cost extraction sources for uranium, will eventually, I'll say, balance things out from an economic standpoint.

[01:08:37]

The whole question, which I don't have an answer for, Mark, is when people can predict that will happen. The issue is it will happen someday – perhaps not in my lifetime, but it will happen.

HIBBS: That was a very good answer to a difficult question. And I have another question, which may be somewhat less difficult, and then we'll turn it over to the floor.

Again, Phil, there's a lot of talk out there about multilateralization of the fuel cycle. A lot policy people are talking about it, a lot of NGO people, government people talk about – heard about it in this panel. But you know, what is – what are the CAMECOs and the AREVAs and the URENCOs of this world think about this? They've actually said precious little about this prospect and I'd be very interested from a commercial point of view about what the players in the market think about the prospects of moving in that direction. Do they support it? Have they embraced it? Is there a roadmap that they can be part of? Where are we on that?

[01:09:46]

SEWELL: Those entities – for example, like AREVA – that already are involved in all the aspects of nuclear fuel cycle and Russia that's involved in all aspects of the nuclear fuel cycle – will have less incentive for multilateralization.

I think the real answer to your question is the incentive to be involved in multilateralization. And it's sort of like market demand will pull in people who need to have an interest in it in order to continue business. I think governments will help dictate the evolution of multilateralization by virtue of what they decide to do in emerging markets. And as emerging markets represent the largest proportion of growth in the nuclear power in the world. And to the extent that policies are established that will incentivize – I'll say the – I'll say take back used fuel, fuel leasing, the guarantee of nuclear fuel supply assurances – to the extent that that requires multilateralization, all of these companies that you mentioned, including my own, will want to be involved in order to increase the sales that they have today to grow.

The question is going to be: Will multilateralization support growth of our industry? And if it does – regardless of whether we're involved in all aspects of the nuclear fuel cycle or just one, we will be drawn to it by virtue of the fact that the multilateralization brings in the demand that is going to be evolving in emerging markets.

HIBBS: Thanks very much.

I'm now going to throw it out to the floor for questions.

Right in the corner here, sir.

[01:11:50]

Q: Miles Pomper from the Monterey Institute.

The recent accidents in Japan – particularly in reactor three – have raised safety concerns about the use of MOX fuel. And I'm wondering – in the middle of this discussion about potential fuel cycles – do you think that's going to raise – shift sort of the emphasis within the nuclear industry and nuclear experts about which fuel should be adopted?

I know that, for instance, Minister Kirilenko made some comments last week about reconsidering the use of MOX and that was particularly noteworthy, I thought.

HIBBS: Who were you directing your question to?

Q: Let's start with Mr. Goldberg and then I guess Mr. Sewell.

[01:12:37]

GOLDBERG: OK. Thank you.

I think it's – actually, I'm not as knowledgeable as you might be on the – on the core at reactor number three. I did see late yesterday there was a piece of correspondence that got into – I think it was with the American Nuclear

Society – having to do with how much fuel – percentage of fuel – of MOX fuel was in the core and potentially what the – what the enrichment of the – across the core is. And it tended to not give the MOX issue as much play as it did earlier in discussions I heard a week ago. So I don't have enough information really to know whether the Japan event has had any large impact on MOX recycle.

HIBBS: Phil?

SEWELL: I would offer the same answer to the – any question involving what's the impact of the Japanese incident on nuclear power, nuclear power growth, on MOX fuel cycle, on expansion of reactors that have particular designs. And that answer is I think we will see not a stop sign with respect to nuclear growth, but a yellow light.

I think we'll see a slowdown of, I'll say, the aggressive actions by people – whether it be in the MOX fuel cycle or whether it be in building new reactors or even enrichment facilities. What they'll do is they'll wait to see what happens with respect to the safety reviews that are going to be ongoing in each and every country by virtue of the incident that occurred in Japan to answer the question of: Is nuclear power still safe; is this incident – is it related to a particular fuel cycle?

[01:14:52]

I think the answer will eventually be that nuclear reactors are safe. Each of the fuel cycles that people so choose is safe with the proper procedures and with the proper designs. And that people will continue, the industry will continue to utilize those and the nuclear power as an energy source will grow and it will emerge.

The only issue I think that we need to answer is how long will it be before it picks up speed again with respect to everybody's perception of what needs to be done to ensure that the safety concerns of a particular reactor design or a fuel cycle design is for the purpose of protecting the public?

HIBBS: Professor Kazimi, you wanted to have a word on that?

KAZIMI: Yeah. Let me just remind everybody that plutonium is present in the uranium fuel reactors. And therefore, you know, if you're talking about near the end of the use of the fuel assembly, we're talking about 1 percent of the heavy metal being uranium – plutonium, rather.

[01:16:10]

When you have a MOX fuel, you start with perhaps 7 or 8 percent of it being plutonium. But we are limited to using about one-third of the total core being MOX. So you end up having a factor of two to three increase in the level of plutonium compared to a uranium-fueled light-water reactor. It's not orders of magnitude difference.

HIBBS: Next question? Right here in the corner, sir.

Q: John Gardenier.

It's been about 20 or 30 years since I've looked at this and I'm just starting to get interested again, so pardon me if I'm way backward in my question.

But my understanding is that France particularly – and somewhat in China – has depended on plutonium fuel for fast breeder reactors and been quite successful with those strategies. And I'm wondering whether they would have any motivations – and this is directed at Professor Kazimi primarily; Mr. Sewell perhaps later – would they have – I don't think anybody's very interested in exporting plutonium-fueled reactor technology to the rest of the world. What would happen to these people in a multilateral environment?

[01:17:45]

KAZIMI: Well, if I understood the question correctly, you're thinking the fast reactor programs in France, Japan and China where they still feel strongly – and Russia, I should say – that this is the future to go to relatively quickly. Would that be different as a consequence of what's happening in Japan today?

Q: Well, you seem to imply that the fast reactor technology would migrate to a uranium-base and away from plutonium. But I don't understand why people would be motivated to do that.

KAZIMI: I think plutonium will always be involved. Uranium would be the initial core, but then plutonium would be generated within the core and to get the benefit of multiplication of energy, you need to get into recycling within that reactor.

What will be different is that it may not be a sodium-cooled reactor. The countries you just talked about have sodium-cooled fast reactors. And if you look at the system, as I describe, you may prefer to go to a different system than sodium-cooled reactors. So the coolant might be different. The fuel is likely to be – after the initial core, it would look the same.

HIBBS: OK. I'm going to have three people ask their questions and then we can turn it over here. So right here.

[01:19:25]

Q: Thank you. Margaret Ryan with *Energy Now*.

None of – there was only one little reference to future technologies that are being looked at such as, you know, transmutation, the actinides and so on. And Energy Secretary Chu has said that's what he wants to see. He wants to see a way for all of us to look at it instead of waste, as a useful product.

Would – do any – anyone who can comment: Do you see any promising technologies on the horizon that would be that fundamental game-changer and change what we look at now as waste?

GOLDBERG: OK, Ms. Ryan.

I did raise that in my remarks. And I'll speak for the laboratory system where I – which I represent: We are working very hard and diligently on these technologies. And you probably have seen or heard there are two technologies that have been out there on reprocessing. Something called UREX-plus and the other one is pyrochemistry. And it's still an evolutionary reprocess that needs additional, you know, R&D and development.

There's also other technologies that are out there even further in the future that have been discussed, such as a fusion-fission approach, a hybrid approach. And there are opportunities. And the secretary is correct to state that going forward, if we are able to find these game-changers – and particularly to reduce the loading at the repository so that we only have to site a much less number of repositories in the future, that would make a huge difference.

[01:21:13]

HIBBS: OK. Mark.

Q: Mark – (inaudible) – National Nuclear Security Administration.

I have two questions, which are related. And number one is: Does the value of stored nuclear fuel, as it decays in heat, offset the value of its storage?

And number two is: What does the mining of old – what would the mining of old, spent nuclear fuel do to actually – to the recycling industry? Is that being considered? I know for a fact, for example, uranium – uranium mine tailings are not being mined, because it's more economical to process. Is it a similar issue regarding spend nuclear fuel?

KAZIMI: You know, I don't know that I've seen an economic evaluation of the value of the reduction in the level of decay heat to facilitating easier time in terms of construction, shielding and handling of the processing of the fuel at the end or handling it even for a repository. So I think the cost-benefits are there and it'll be good to see where the value is, but I haven't seen it done.

[01:22:43]

The second question is a little bit more complicated. I'm not sure I have a crisp answer for you. What were you thinking of?

Q: (Off mic) – resources actually represent a resources which is there.

KAZIMI: Yeah.

Q: And so could you mine those to actually extract plutonium? And how do they play in the general economic of the system? All the spent fuel that's stored now in nuclear power plants in the U.S. – U.S.-wide – could they be considered as a resource of uranium or is it too small to make a difference – or plutonium or is it too small to make a difference?

KAZIMI: Maybe I'll let Steve, who has done some –

GOLDBERG: Yeah, yeah. Actually, there are two resources that are clearly in play here. And that is depleted uranium, because uranium would have burnt down and you might be able to use it as feedstock in re-enriching it back up to 3-to-5 percent.

And the second is, you know, if we had a plutonium economy, the question is at what cost? And I think the – right now, we don't have good economics. Good being it is cost effective to go and mine out that spent fuel, because right now it's an expensive proposition. And relative to the value you're going to get in the marketplace for those resources, it doesn't counterbalance very well.

[01:24:15]

There was a study done – I think about three or four years ago by AREVA – on what they called their technology for reprocessing. And they looked at the value of the recovered uranium – and also the reduction in the heat load for the repository for the spent fuel and they did some sort of balancing act.

But again, it's very dependent on what you assume the repository costs to be. And because we do not have very good numbers right now on that side of the ledger, it's very speculative to be able to do that kind of a calculation.

HIBBS: I'm going to take one more question right here.

Q: Sinan Ulgen with Carnegie.

I have a question to Mr. Goldberg and Mr. Sewell about the commercial aspects of the multilateralization of the fuel cycle.

You have stated that going forward, one of the dynamics that we shall see is the reactor supplies coming with bundled offers – both on the front and the back end. We also see some examples of that in the emerging markets.

[01:25:37]

But if that is so, what is the interest for those countries that have – that basically champion their nuclear technology and their reactor suppliers for multilateralizing this? Because that is going to do away with their competitive edge. And if that analysis is correct, then how do you reach the critical mass in the multilateral domain, which would incorporate both the back end and the front end? Because if we don't do that, then obviously the winner is clear.

GOLDBERG: Yeah. I'll jump in first.

That is an excellent question. I actually think that is the fundamental question that really, going forwards over the next decade or – decade – let's say next decade – is critical, because reactor suppliers have a nature of trying to bundle it up in a way that services their unique individual needs and doesn't necessarily service the wider community. You know, when you bundle – when you look at a lot of people going across the supply chain.

[01:26:47]

So yes – and I think it goes back to my earlier slide where I was trying to show the advantages and disadvantage of multilateralism. And the key advantage, if you're going to get one, is economies of scale. You've got to have scale to be able to pull it off, because a government cannot front-end this cost long term. It has to eventually take off as a commercial enterprise. And if we don't have enough scale in the system, the multilateral approach will not work.

So the issue of bundled fuel sales connecting with multilateralism is a great question, one in which I think – in our work on the Global Nuclear Future Initiative – we are taking on as a key issue. I don't have a very clear answer for you, but it's one in which we need to focus on.

SEWELL: In the interest of the cocktail hour, I will agree with him. (Laughter.)

GOLDBERG: Phil doesn't agree with me that often. So that's good. (Laughter.)

HIBBS: OK. Let's have a round of applause for all three speakers. (Applause.)

And I'm going to close it off and enjoy your cocktails.

(END)