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ADVANCED NUCLEAR ENERGY AND THE BATTLE AGAINST CLIMATE CHANGE

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P R O C E E D I N G S

(Video played)

MR. MURO: Good afternoon, everybody. I'm Mark Muro, senior fellow and policy director at the Metropolitan Policy Program at Brookings, and it's my pleasure to kick off what I think will be a stimulating hour, for sure.

I'm excited about this, as a pretty serious advocate myself of the necessary role of technology innovation in our society, not just to make clean energy cheap, and that's one of the crucial goals, but in fact, to deliver broad-based prosperity in the world. Work I've engaged in with the Breakthrough Institute, the American Enterprise Institute, the World Resources Institute and Clean Energy Group has helped make clear that we need to deploy a massive surge of technology innovation to have any chance of improving access to modern energy in the world, while stabilizing greenhouse gas concentrations at acceptable levels. Technology innovation is going to be critical in the energy space.

At the same time, work I've done more broadly at the Metropolitan program is focused on the central role in developed economies of what we call advanced industries. In general, R&D and STEM worker-intensive industries, ranging from aerospace manufacturing and auto making to solar energy generation to high tech services: software, computer systems design.

These innovation industries are crucial to prosperity broadly, while they directly or indirectly support about a quarter of employment, 60 percent of exports, 80 percent of patents, 90 percent of private sector R&D. These industries are crucial to our economy.

The nation's advanced industries populated with both Fortune 500 companies, but also small, cloud-powered startups represent the crucial site for

technology advancement, and so, human achievement in the world and in this country. Why are we so passionate about this sector, this suite of activities? Because it's transformed life and society.

Advanced industries have sequenced the genome. They've delivered blockbuster biotech drugs and high yield seeds, and now, they're building the mobile Internet to bring billions of the globe's citizens into the connected world. The iPhone is an exemplar of advanced industry progress. So too, is hydraulic fracking, which has completely changed world energy markets.

And so, the key point I have is that technology innovation in the advanced industry sector is delivering extraordinary productivity gains to people and to society. Why is productivity soaring in most advanced industries? Because these industries are succeeding at making most everything smaller, faster, safer, cheaper and more efficient.

Why are computers and appliances all cheaper today than they were 25 years ago? Because of innovation in these industries. And I would add to the extent that humanity improves access to modern energy for the world's poor while mitigating the worst aspects of climate change, it's going to owe it to that progress -- to advanced industry's technology gains, which brings us to our topic today, the accomplishments, problems -- we're going to acknowledge the problems, but also a recent renewed potential in the U.S. nuclear industry.

To quote a recent manifesto on the world's environmental future, nuclear fission today represents the only possible present-day zero carbon technology with the demonstrated ability to meet most, if not all of the energy demands of a modern economy. And in fact, in the 1960s and 1970s, the nation embarked on the kind of

needed scale up through the construction of a hundred-odd light water reactors in this country, and dozens of others around the world.

You know, I think Josh Freed, who we're going to hear from, has told this story extremely well. There's very much an expansion of the U.S. advanced industry sector, by the way, to do this, and as Josh has written, U.S. engineers drew up the plans. U.S. companies like Westinghouse and GE built the plants. U.S. factories and mills made the parts, and the Atomic Energy Commission designed the safety standards.

But then, this technology went adrift with cost overruns and the bizarre confluence of "The China Syndrome" movie and the Three Mile Island incident followed by Chernobyl, a bizarre set of events, but it led to a period of drift.

So, there's much to talk about today about what went wrong and how momentum can be restored, but the crucial fact, I think, is that a new, promising confluence of generational change, societal urgency about climate change and technology progress is making this actually a hopeful moment. This is the advanced nuclear ferment we're here to talk about today.

Suddenly, the emergence of a new generation of safer and cheaper new technologies, the interest of smart young engineers like Leslie motivated by climate concerns and the money and venturesomeness of the high tech investment community in this country and others, is creating something of a startup feel in an arena that has felt more like a zombie industry for a couple of decades.

In a word, a once sleep legacy industry has garnered a little of the high tech buzz that other legacy industries have begun to reclaim, such as the auto sector. Just as auto making has been transformed by the conversion of the vehicle into a digitally robotic device, so too, may future reactors be higher powered, vastly safer and small and

efficient enough to be built in a factory and moved by rail. That's a vision.

And that's since Leslie's molten salt units may one day emerge as the iPhone of advanced nuclear, so we'll see about that (Laughter). But indeed, if that happens, nuclear energy though, may actually meet its potential as a climate mitigation technology.

And so with that, I'd like to get our program rolling by handing this to Steve LeVine, the Washington correspondent of Quartz, who will be our moderator and introduce our great panel today. And I just want to put in a plug for his outstanding book, "Powerhouse," on battery technology, and worked ongoing at Argonne National Lab, which is excellent and not entirely irrelevant to our conversation. So, Steve, I'll hand it to you.

MR. LEVINE: Thanks, thanks. Thank you, Mark. Thank you, Brookings, for organizing this terrific panel today. It's a privilege to be here with this particular grouping of panelists. And also, this is such an under covered and under appreciated topic, and the overflow crowd, I think reflects that.

We're going to discuss today where nuclear power is now; has it overcome some of the doubts that have arisen in recent decades about it, because of accidents, most recently, Fukushima. And if so, why? Where is the industry? Where is it going domestically and globally?

So, let me give a very, very brief -- in the pre-see that you have in your hands, you've got biographies of the three panelists. Charlie's is by far the longest (Laughter).

MR. EBINGER: That's because I'm the oldest (Laughter).

MR. LEVINE: So, I'm going to give just a very brief intro. I'm going to

ask each one of the panelists a question. And then, what's going to happen, I hope, is they will engage themselves in a conversation. That will go till about a quarter after, or at most, 20 after, and then we'll open it up to discussion. However, we're not operating in a constrained environment. If you absolutely cannot restrain (Laughter) yourself, feel free to ask a question right in the middle of it, but just identify yourself first.

So first, to my left, Josh Freed. He's the author of a terrific essay that appeared on the Brookings web site. If you have not read it, you must read this, not just for the substance, but just because it's a great read, and I appreciated it as a writer.

So, Josh is vice president of the Clean Energy Program at Third Way. Prior to that, he served for a decade as a strategist for public advocacy, corporate, and political campaigns. He was a senior staffer here on the Hill, and there's a list of Congresspeople who he worked for, and you can turn to that.

And then, we've got Leslie Dewan, who is to Josh's left, and she is the main character in his essay (Laughter). And so you'll see that. And so we're privileged to have Leslie here.

She's a co-founder and the CEO of Transatomic Power. She graduated recently with her PhD from MIT in nuclear engineering. Her focus was computational nuclear materials, something that made me want to have Leslie's biography. So, she was a *Time Magazine* "30 People Under 30 Changing the World," and an MIT Tech Review “Innovator Under 35,” and (Laughter) a Forbes "30 Under 30" in Energy.

SPEAKER: Wow.

MR. LEVINE: I'm sure that that's the abbreviated version. And Charlie, all the way to the left at the end of the table; he's a senior fellow in Energy Security and Climate Initiative at Brookings. Charlie founded that initiative, and he ran it for six years,

and only recently decided -- I guess Charlie, did you just decide you wanted to write more?

MR. EBINGER: I decided I wanted to work less (Laughter).

MR. LEVINE: All right. So, Charlie has a long career -- I mean, apart from Brookings, a long career in the private sector, the government sector, including -- he was a senior advisor at the International Resources Group, where he advised over 50 governments on various aspects of their energy policies.

Charlie has special expertise in South Asia, the Middle East, Africa. He's also worked in the Far East, Southeast Asia, Eastern Europe. Charlie, it's naming every place in the world (Laughter). The Arctic's not here (Laughter). Okay.

Anyway, so everyone will have a chance to speak. So, let me start with Josh. Josh, why don't you, if you don't mind, catch us up after Three Mile Island? Where are we in the nuclear industry right now? What's the difference between what blew up there at Chernobyl, Fukushima, and what we've got now? What are misconceptions (Laughter) and -- yeah, just sort of brief us.

MR. FREED: Well, I'll try to give you a thumbnail sketch on where we are now, and then, we can have the broader conversation, both about nuclear as it is today, and why we think advanced nuclear technologies are so important as part of the broader conversation.

The key difference is -- there is a big difference between what was developed, built, and had the major problems at Chernobyl, and the nuclear reactors in the United States and most of the rest of the world. The key thing is a containment vessel, which is a huge steel vessel that you see -- under construction or in the photos, it's a half round building that's part of the reactor.

And it's designed -- it's a containment vessel -- to contain any problems if there is an explosion or a crisis at a reactor involving a meltdown. Unfortunately, the Soviet-era designed reactor at Chernobyl did not have one. And so, when there was a meltdown, that was due to problems with the operations at that facility. You saw the explosion, the release of radioactive material and all of the subsequent problems there.

That did not happen at Three Mile Island. As a matter of fact, very minimal if no radioactive material was released. There were no injuries or deaths, and while the reactors were shut down, the process to respond to the crisis was successful. And it's important to note both that, and then also, the broader history of operating nuclear reactors in the United States. They have an extremely safe track record, and they have it period end stop on their own. And then, when you look at it compared to other energy sources, particularly coal, the nuclear sector looks even more sterling.

And the key thing when you take a step back from that is, well, why? And for us at Third Way, you know, we're an organization that was developed to challenge orthodoxies from all political ideologies to find what the really pragmatic solution to many of the challenges facing the country are. And for the Clean Energy Program, that's climate change.

As we looked at the data that the UNIPCC, that's the climate change organization that the UN founded, the International Energy Agency, the EPA and many others came out with. The data was stark. It's clear that we needed nuclear energy to provide 65 percent of all zero carbon emissions in the U.S., about the same around the world, if we have any hope of reducing carbon emissions and meeting global energy demand. And so, that's what led us to look at both nuclear as an energy source and advanced nuclear and spurred the essay that we ended up writing.

MR. LEVINE: Great. Great. Thank you. Thanks for that overview. Leslie, so you are running, straight out of MIT, a startup – a nuclear startup. I think it would be very useful. Just talk about that. Talk about your startup.

MS. DEWAN: Absolutely.

MR. LEVINE: Okay.

MS. DEWAN: So, I started the company with my cofounder, Mark, who was also featured in the video when we were midway through grad school, when we were midway through our PhDs. So, we had a few very, very busy years, and then, I graduated back in 2013. The last two years have been full-time with Transatomic.

And for me, it's just such a thrilling time to be in the industry, because there are so many new designs that are being developed, and people are taking different approaches to commercializing them. So, in addition to new designs that are coming out of universities and national labs, there are a large number of startups across the country and across North America and around the world that are focusing on commercializing a new nuclear technology.

So, I think in the recent Third Way report, they found out that there are, I think, 46 different nuclear startups worldwide. Which is --

MR. FREED: Just in North America.

MS. DEWAN: Oh, just in North America. Yeah. So, that's amazing. And it's something that, for me personally, I find it like very satisfying to be working in the nuclear field, because I became a nuclear engineer in the first place, because I'm an environmentalist. I think that we need nuclear power alongside solar and wind and hydro and geothermal, if we want to have any reasonable hope of avoiding the widespread environmental devastation caused by fossil fuels, and coal, in particular.

So, being able to see Transatomic's design and the suite of other designs that exist moving towards fruition and raising funding and doing experiments and putting new things together, just makes it a really exciting time.

MR. LEVINE: Can I just follow up? Could you give just a thumbnail on the science of what you are doing? What is the thing you're doing?

MS. DEWAN: Oh yeah (Laughter). So, we're commercializing a type of what's called a molten salt reactor. Molten salt reactors use a liquid fuel rather than a solid fuel. The baseline design was actually first developed at the Oak Ridge National Lab back in the 1960s, and they showed that they had an extremely, extremely safe type of nuclear reactor that, in effect, couldn't melt down, even if there were no operators on site, even if it lost external electric power.

That design, at the time, it was abandoned, ultimately, partly because it needed some highly enriched fuel, partly because it was expensive. But mostly, because no one really cared about the safety benefits, because it was before there had been any significant commercial -- any commercial nuclear accidents.

So, that got kind of pushed to the wayside in favor of other technologies. What my company was able to do, just in like a 20 second nutshell, was change around some of the materials and geometry in the design to make it much more compact and power-dense and cheaper, potentially about half of the cost of conventional nuclear power on par with coal, while keeping the same safety benefits of the original design.

MR. LEVINE: Great. Thanks. Charlie, I want to broaden this up and get a global perspective. We've heard since Fukushima, Germany, France, Japan have all taken various degrees of a retreat from nuclear. China did temporarily. I'm not sure where it is now. Could you give us a view of where the nuclear energy industry is

abroad?

MR. EBINGER: Sure, Steve. With the exception of a very few countries, the nuclear industry abroad is, I think, in big trouble. After Fukushima, Japan closed 54 of its nuclear reactors. They are now talking about bringing back two in the near term, and with the debate still raging in Japan, how many to bring ultimately. This has had a devastating impact on the Japanese economy, because all their fuels are imported, with the exception of nuclear. And so, they've seen their bills for oil, coal and particularly liquefied natural gas skyrocket.

Germany has also made a commitment under their Energiewende to make a massive, accelerated effort; transition to renewables. And whatever you think of the German situation, and it has some big problems, but it has created a very dynamic renewable industry in a very short period of time, getting somewhere around 27 percent of its electricity currently predominately from wind and solar power, and on track to get much higher levels. Again, whatever you think of Germany, it is a case study of a country that, once the commitment was made, does show that transitions can occur quickly.

The one very bright spot in the world for nuclear power is in China. It has 23 reactors in operation, and another 26 plants under construction. And China has plans, most of which are based on a Westinghouse design, ironically -- China has plans to develop a subtype of their existing reactors that they've gotten from imported technology, and they've become a significant potential exporter of nuclear technology, which worries some people of whether China will have the same concerns about safety and proliferation that traditionally, the Japanese, Americans and European vendors have certainly had.

India has very ambitious plans for nuclear power -- very ambitious plans.

But the reality is, they continue to fall short. There are only four reactors currently in operation, although they have plans for many, many more. The problems in India are with the press of population. The reactors take a lot of land, consume huge quantities of water, which is in scarce supply and has generated a lot of opposition based largely on farming interests, because of the concerns both about the use of water and the possible contamination of water.

Around the world, the Russians are still vigorously pushing ahead with nuclear power. They too, have in the not too recent past, entered the export market selling reactors in some cases that are not even operating in Russia itself, which is never a good idea. You kind of want to make sure you're dealing with proven technology.

And a few other places around the world that are promising -- the United Arab Emirates has a few years ago decided to purchase four reactors, actually from South Korea, who is also emerging has a major nuclear export vendor, although they've had some very serious quality control problems in their own reactors back in South Korea that have led to some concerns about whether in their exports, any of those same problems exist.

The United States, you know, we have a 104 reactors operating. The tragedy, in my view, is that you know, we have been closing down some reactors prematurely for a variety of reasons, most of which I think center on the fact that in deregulated markets in about half our states, and particularly with large volumes of cheap natural gas, it's very difficult for those reactors to compete.

We've also, I think, seen a misguided potential Environmental Protection Agency policy which does not allow the construction of new reactors except for the four or five currently under construction in various states, actually, to be part of the

compliance program when the EPA's resolution finally goes into effect.

So, that in a nutshell, you know, there are bits and pieces of reactors in Eastern Europe and other countries, but it's really China, India and Russia that are the big stories right now. But these are the conventional reactors. They aren't the reactors Leslie and her cohorts are talking about. And all I can say is, as a longstanding supporter of nuclear technology, thank God you're coming along (Laughter).

MR. LEVINE: Charlie, can I ask you -- the reactors that -- for example, that are going up in China, are they -- when they talk about second, third and fourth generation technology, where do these fit, even if they're not the type that Leslie's talking about. And just one more thing. The politics in Japan -- can you imagine that the politics shifts again and perhaps more advanced reactors start up there?

MR. EBINGER: Most of the Chinese reactors are what we call generation three reactors, which are not state of the art like the reactors that are attempting to be built in Finland and France, which sadly have proven to be financial albatrosses. Both those reactors are nearly five years behind schedule and six billion euros over budget.

But the Chinese are looking at generation four reactors as well, which are more of the passably safe designs that people in the conventional industry still hope will have a resurgence. I have my own doubts about that possibility, and mainly because of cost. And Japan, Steve, it goes back and forth. But talking to my friends at METI and elsewhere, I would bet that if you could have 15 reactors back on by 2030, you'd be doing well.

It is almost across the board, across political parties, with the exception of the very elite and some of the business community, Fukushima was such a traumatic

accident, it's going to be very hard to see the Japanese make the decision to bring them all back on board.

MR. LEVINE: Yes. Okay, thanks.

MR. FREED: Can I --

MR. LEVINE: Yes.

MR. FREED: Just one point on the Japanese experience. I mean, it does show the challenge that Japan, in particular, faces, where both economic pressure, and depending on how climate negotiations proceed internationally, they are caught between a rock and a hard place, where if they don't bring additional -- their existing reactors back on line and eventually -- and eventually add advanced reactors, they are going to face very significant cost pressure on energy, because they're importing all of it. And they're going to face very significant pressure on carbon emissions.

MR. EBINGER: Absolutely. And their carbon emissions have gone through the roof since Fukushima.

MR. FREED: Yes.

MR. EBINGER: And keep in mind, too, that the Japanese were one of the few countries in the world that actually had made a major bet on commercial reprocessing of spent fuel, and have put literally, billions of yen and dollars into developing those facilities. And now, it's a question mark. You know, well how many people are really going to be wanting their reprocessed fuel? Not in Japan.

MR. LEVINE: Yeah. So, along these lines, let's stick with politics. Let's shift to the U.S., and this is for the group. This is for the group. What are the politics of nuclear in the United States? Where is it? Where does it need to go?

MR. FREED: I'll take the first stab at it.

MR. LEVINE: All right.

MR. FREED: I mean, look, I think the politics of nuclear are changing on generational lines. What we found as we started doing research on both the essay and talking to staff on Capitol Hill within the administration and other places, is that the imperative of climate change has prompted a fair amount of progressives who view themselves as climate hawks to reconsider what used to be sort of a grounding position of environmentalism, which is that nuclear needs to be replaced.

And now, what we're hearing increasingly is people are comfortable with technology. They are comfortable with the development of new reactors, both the generation three plus reactors that are being built in Georgia and South Carolina, and especially, the promise that reactors like the one that Leslie is designing, hold, because we're going to need both a dramatic increase in the renewable energy sources, wind and solar that are being deployed here and abroad, but also, a lot more nuclear, if we have any hopes of keeping to -- close to the carbon emissions limits that most respected climate scientists have agreed upon.

And just an example of that is Senator Sheldon Whitehouse, who is the head of the Climate Caucus in the Senate. Senator Whitehouse really has taken a lead in the U.S. Congress in advocating for advanced nuclear has part of the climate solution. And that's a big generational shift from what you saw 5 or 10 years ago, let alone farther back.

MR. LEVINE: Leslie, just the same topic. Isn't there a money issue? There's a funding issue. Right?

MS. DEWAN: Pardon?

MR. LEVINE: Funding issue.

MS. DEWAN: Certainly. It's something that in many ways, it can be tricky to get funding for advanced nuclear from private investors, and that relates not so much to uncertainty in the technology, but due to uncertainty in what the regulatory pathway will look like.

So right now, there's no rapid commercially viable pathway for getting a license for an advanced to generation four nuclear reactor in the U.S. And some estimates have said, well, it might take 20 years from now to have a pathway, or longer. It might take $500 million to have such a pathway or more, just for one particular design.

And it's really the high cost and long timeline, and even more so, the uncertainty in the cost and timeline that can make it tricky to get larger scale investment. Though the one piece that I want to emphasize is that there has been a large amount of private investment in nuclear in the U.S. just over the past few years. I think up to $1.3 billion total.

MR. FREED: Yes.

MS. DEWAN: So, large amount of that capital has been deployed already. But to move further and to bring different designs to fruition, I think it's necessary to have a more -- to carve out a more streamlined regulatory pathway for these newer designs.

MR. LEVINE: On the same line of inquiry, the monumental costs, which we know that a conventional nuclear power plant costs -- you startup guys, is it the same economics, these huge --

MS. DEWAN: So, a lot of the advanced reactors, they have benefits in terms of the total cost is less, and also, it takes less time to build, so it can take, in the case of some designs, about half the time to build, so your financing cost is a lot less.

So, that can make it much more attractive economically, though that's with the caveat of none of these have been built yet, and it's an advanced design. So, there's some error bars around those numbers, certainly.

In terms of -- sorry, I've completely forgotten my second point I was going to make (Laughter).

MR. LEVINE: No, I was wondering, are the economics different for a startup than it has been this big hurdle for the conventional actors?

MS. DEWAN: Yeah, certainly. Like the larger -- it's tricky in a startup to be working on something that's both high tech and very large -- has the large timelines and the large dollar amounts. And so, I think that's why a lot of the startup designs have been moving towards more modular deployable reactors, reactors that can be built more quickly and for a lower total cost.

But one of the nice things -- just one quick anecdote. Our main backer is Peter Thiel's Founders Funds. And after conversations with a few VCs where they said, 'Oh, this will, you know, cost a few hundred million dollars just to get to this phase. It will take 9 or 10 years just to get to this one particular milestone that you've set out.' A lot of VCs said 'No,' and we talked to them, and they said, 'Oh, well that's about how much the Falcon 9 rocket cost, and how long it took to deploy that.'

They were a big early investor in Elon Musk's SpaceX. So, they said okay, well, advanced nuclear is kind of within our wheel house, because we've done big aerospace investments before. So, I see a lot of parallels with that industry.

MR. FREED: And another thing, we released a paper that Leslie alluded to that surveyed the advanced nuclear space in the United States and Canada, and found upwards of 45 to 50 companies and institutions developing advanced reactors.

And what was striking when we talked to almost all of those companies was that they were built both on a technological model, but also a business model.

And there is a real understanding that if you're going to be successful with private sector-funded advanced nuclear, you have to have a business case where you compete on cost and reliability against other energy sources. And so, we hear a lot, 'This is how we're going to reduce the cost of construction. This is how we're going to be modular. We're going to be built in a factory as opposed to on site.'

And you can see a real change in approach in thinking that recognizes, there is an economic opportunity not just to address climate change and save the world, but also, make our investors a lot of money in the process. And that's enormously different from what we've seen in the nuclear space and a lot of energy space up until now.

MR. EBINGER: If I could just -- go ahead.

MS. DEWAN: Thank you so much. Just to emphasize one particular part of what Josh said, is that we definitely view ourselves as not competing against other advanced nuclear designs or other existing nuclear designs. What we need to do is compete against coal; be cheaper than coal, be as close as possible to natural gas in terms of cost, because that's the fight that really matters, being cheaper than the other fossil fuel sources.

MR. EBINGER: I was just going to add, I think the critical thing is to get the modular size, because at this point in time, you know, to go to your board of directors as a utility executive and say you're proposing a 900 or 1,200 megawatt reactor, I'd think you'd be laughed at, if you weren't removed as CEO (Laughter), because the reality is, whether sadly or good, is that we are awash in natural gas.

MS. DEWAN: Mm-hmm.

MR. EBINGER: I mean personally, I think the natural gas numbers that we throw about in terms of reserves are probably low. But even the conservative numbers say we have 85 to 90 years' reserves at current consumption levels. And most people do not believe that natural gas is going to rise dramatically.

Now, you know, that can always be a wrong assessment, if we have a fracking accident and people demand that we close down fracking. But on current trends, no one rejects, so that is unlikely to change. But on the other hand, on the urgency of nuclear, I think it's made all the more manifest in that as we look at carbon capture and sequestration, which has been touted as you know, the way to save the use of coal in the world, the reality -- and we're doing a study on this right now and I've visited a few of the existing plants that do exist -- the reality is this is far away from mass commercialization, and the costs are staggering.

So, we've got to find a way to bring on these new reactor designs. And if I could just make an anecdote, you know, my father was the top aide to General Groves on the Manhattan Project. And when I look at what they did with the Manhattan Project when they had to do it, and last night, I was watching “The Roosevelts,” and they were talking about how President Roosevelt in 18 months, had 55,000 bombers made in World War II.

When you see what the U.S. can do when there's a threat and there's a perception like climate change that we have to do it, I'm not convinced that we can't accelerate Leslie's type of technology and get on with the job.

MS. DEWAN: Mm-hmm.

MR. LEVINE: Okay. But what about this -- what about the issue -- I'm

wondering how do you navigate these politics; the really global politics of 'Yes, we want to power our countries, our cities, but we don't want to frack? We don't want nuclear power. We don't want coal. We don't want oil.' How do you navigate this --

MR. FREED: Well, but I mean --

MR. LEVINE: -- to get there?

MR. FREED: -- I think there are only a select few countries that are actually saying and doing that. I mean, Germany is sort of an example, but they're purchasing nuclear from across their borders, and they actually --

MR. LEVINE: And coal (Laughter).

MR. FREED: And coal.

MR. LEVINE: Mm-hmm.

MR. FREED: And when they shut down the nuclear plants they had, they saw emissions rise significantly. Italy's looking at building a reactor. The United Kingdom is. We're fracking here. China's building pretty much everything right now. So, I think the question that people in a lot of places are actually asking, is how can we power our country cleaner, cheaper and more reliable. Period.

MR. EBINGER: There is a lack -- I mean, I think one of the biggest problems I encounter is the people who do not understand that unless we can develop large scale battery storage and prove that that technology works, that there is no way that wind and solar can do it alone. And yet, there were many people, when I testified on the Hill, who believe that.

But if you look at almost all of the forecasts, and forecasts can be right, forecasts can be wrong. But from the International Energy Agency or you name it, no one is projecting that by 2035, 2040, that the world is going to get much more than 20 to

25 percent of its electric from renewable. That's a huge growth. And I mean, it will probably be the fastest growth of all fuels.

But it starts from such a low base that to overcome the fossil fuels and the nuclear's contribution, it's a prodigious effort. But I think one of the problems we have is this lack of education on what can and cannot be physically done.

MR. LEVINE: Let me throw out one more question, and then we'll open it up to the audience. But speaking of politics, whatever the subject, we seem to blame China for it (Laughter). Or Putin. But in this case, China has raised -- if the United States continues on its path of not developing its nuclear, that another country, for example, China ends up in the leading role, and what that would mean, and then these ominous clouds come, and what that means. So, Charlie, is this a real -- should be worried about this?

MR. EBINGER: Oh, I think on the basis of current trends, it's inevitable, if we don't turn it around and find a way to get our reactors back into the marketplace.

MR. LEVINE: But is that bad?

MR. EBINGER: It'll be China and Russia who are the big nuclear export countries.

MR. LEVINE: Is that bad?

MR. EBINGER: It doesn't have to be bad, but as I said, I think some of the Russian reactors have not had the full range of testing or regulatory oversight that I would want before you start exporting those into other environments. They're exporting into countries that don't have any kind of institutional infrastructure or a cadre of trained people like Leslie, to actually run them effectively.

So, there are concerns, and proliferation -- you know, the concern I have

is the traditional vendors drop out of the market and you throw in the South Koreans into the mix. And if the market remains small because of the concerns we've talked about, the risk of various vendors begging thy neighbor to cut back on safety concerns or proliferation concerns -- I don't want to overstate it, but I don't think it should be ignored, either.

MR. LEVINE: Josh?

MR. FREED: I mean, it depends on where your interest is coming from. I mean, I share Charlie's concerns, and I think for U.S. policymakers, you know, their motivation is what's in the best interest of the U.S. And if the best interest of the U.S. is to have the Nuclear Regulatory Commission set the gold standard for nuclear regulations around the world, having another country dominate the most advanced technologies, probably not a good thing.

And the same thing goes if we find that the U.S. nuclear supply chain starts to wither and disappear, because most of the nuclear reactors and most of the knowledge base, including Americans like Leslie and others who are developing advanced reactors, have to move their companies to China, that may fine for reducing emissions, but it's not good for the U.S. economy.

So you know, and I think we've heard estimates that China could develop and commercialize advanced reactors as soon as 2025. So, if you are a believer in climate change, as we are, there's real urgency to get these reactors stood up and commercialized to address climate. And even if you're not, there are a lot of other imperatives, if you're elected or you're working to figure out what the best interest of the U.S. is, to really push this.

MR. LEVINE: Leslie?

MS. DEWAN: So, I completely agree with what's been said before. And China, in particular, is devoting billions of dollars to both developing advanced nuclear reactor technologies and developing a pathway for the commercialization of those advanced technologies within China. And I think the U.S. really runs the risk of losing its place as being the forefront of advanced nuclear technology.

As Josh said, there is a number of companies that were originally founded in the U.S. that see the pathway for commercialization as being too difficult here, so they're investigating other countries. They're looking at Canada or China or the Philippines or Malaysia, because they see it as being easier there. And that's a very concrete example of the U.S. literally losing its advanced nuclear technology to China, because we weren't able to move rapidly enough here.

And again, I mean, I greatly admire the work of the U.S. Nuclear Regulatory Commission, and they are now the gold standard of reactor licensing worldwide. But I think it's necessary to potentially carve out an additional path within the NRC for advanced reactor technology, so that we don't lose our current lead in this nuclear tech.

MR. LEVINE: Interesting, interesting.

MR. EBINGER: Very good.

MR. LEVINE: So, let's open this up. If you have a question -- so we already have some. Identify yourself, and then if you can just point to who you want to ask. First question. Yeah?

MS. SUGAR: Hello. Patricia Sugar for Pipeline (Inaudible) Gas (Inaudible). Well, thank you very much for this very interesting panel. It's a very interesting topic. Innovation is taking off unexpectedly for most of the country and you

show it really well in your book, "Powerhouse: The Innovation Quest."

I just came up from an event at the Atlantic Council on the (Inaudible) security, the next battleground. It seems like the word battle was coming up quite often in this. And the keyword was adaptation, about how more attention was needed to reach the goal.

And one thing that strikes me that you said was about finding a regulatory pathway. And I was thinking, is there a dashboard? Could a dashboard be created for progress and to help (Inaudible) innovation? Thank you.

MS. DEWAN: I think that's -- I can take a first stab at this. I think right now, the biggest issue is the ambiguity in the total cost and the total timeline of the pathway. There is no such dashboard yet. There is no such transparent checklist for advanced nuclear reactors. There's a very well established one for light water reactors, for the conventional designs, and that works very well.

But I think it needs to be broadened, so that we can have that same type of increased certainty and clarity in terms of how long it will take and how much it will cost to bring in advanced reactor to commercialization.

MR. FREED: I mean, I think on the regulatory side, and also, just in terms of how Washington thinks and handles nuclear, we're seeing the same -- the equivalent disruption that we've seen in a lot of other industries, where you've got, for the first time ever, really, private sector companies who are seeking to develop this technology with private dollars, and coming to regulatory agencies and saying, ‘Hey, here's our design. Could we get a sense of where we'd be in the approval process and how much it would cost, so that we can raise our next round of money and then come back to you?’

That's just not how it works, because the NRC was created to regulate an existing fleet of developed and commercialized technologies, and they do it quite well. And so, we're facing a situation, once again, where the government needs to play catch up. I think we can do it, but it really just needs -- we need to create the will here to figure out how.

MR. LEVINE: Okay, good. Let's take this all the way in the back, and then this gentleman. Yeah, you can go ahead and stand up, sir.

MR. WILSON: Good afternoon. I'm Patrick Wilson. I work for the Babcock (Inaudible) Company, one of the last remaining companies in the United States that's in this sector. And actually I'm not working for them anymore, because as is acknowledged, they will have decided to walk away from producing revolutionary, affordable small scale nuclear reactors in the United States, most because of the valley of death that you (Inaudible).

To get from to creation, right, to your first customer, could be a 10 year, billion dollar (Inaudible). So my question, Charlie -- it's your fault. You brought this up (Laughter). How do we expect any company, not just American companies, to get through that valley when we're in the midst of taking away international project finance from U.S. companies?

You know? I admire all of these young entrepreneurs trying to do this cool stuff. But if you can't sell it, the Chinese just lost a huge infrastructure bank to (Inaudible). I'm just wondering, how do you see getting through that moment?

MR. EBINGER: Well, it's not a good answer, but exactly what you say. We don't decrease our export capability with the Ex-Im Bank and other such institutions. We actually, I think, need to increase the lending authority. I think we need to have a firm

commitment from the Department of Energy to really put some advanced, much more than -- they put a lot of money behind nuclear research, but I think they could put a lot more behind advanced nuclear reactors.

And we need an administration, quite honestly, that's committed to nuclear power, and I don't believe this one has been. Whether that could change over time -- I mean, the fact that we had a blue ribbon commission on nuclear waste and we still haven't exercised any of the options that were proposed. What's the point of having a blue ribbon commission?

So, I think you need an administration that's committed. You need more R&D by the Department of Energy, or -- and more tax credits and supports for companies like Leslie's. I know that's not popular in Washington, to talk about more tax credits. But they need it, if you want this technology to thrive.

MR. LEVINE: This gentleman -- right. Sorry.

MR. SPRINGER: My name is Jim Springer. I was interested in the comment about being cheaper than coal -- natural gas. And I wondered if -- I know this is all very early stages -- if you have a sense of what the cost of power (Inaudible) be profitable for a design like yours. And given the pressures of natural gas, do you compete well in wholesale (Inaudible) markets, particularly in balancing the intermittency of renewable energy, if these small, modular reactors have greater benefits in that regard, as far as partnering with renewables.

And separately, (Inaudible) -- what you see as maybe some of the ways forward in dealing with the waste issue. I know that your video said that there's significantly less waste in smaller advance reactors.

MS. DEWAN: Mm-hmm.

MR. SPRINGER: But internationally, in particular, that's a huge concern, (Inaudible) get regulatory oversight. If there are any ways under development to be able to support (Inaudible).

MS. DEWAN: So, just to talk about the cost numbers, quickly. So, with our current cost estimates that were done externally, we're able to be on par with coal, but not cheaper than the very cheap natural gas prices that are available in the U.S. right now.

So, our technology in all forms of nuclear have very, very low generation costs across the board. It's the construction costs that can really trip you up. So, we're aiming to get our construction cost as close to the incredibly low construction cost of natural gas, as possible, and keep it below coal. Do you want to talk about that?

MR. SPRINGER: I'm sorry. But the other part, how do your reactors play with like (Inaudible) renewables? Is there advantages to the advanced designs (Inaudible)?

MS. DEWAN: So, the advanced nuclear reactor designs are slightly better at load following. Like they can do load following on like a 12 hour or 24 hour schedule, but they can't -- they don't have the peaking that you can do with some types of renewables. So, we generally see even the advanced reactors as doing primarily base load with some potential for fluctuation on a daily basis.

MR. EBINGER: On the waste question, it's never popular. But get on with Yucca Mountain. You know, we studied it for years. We spent billions of dollars. We have a national law that says the government's supposed to be taking nuclear waste.

And the other facility that I think we need to revisit is the waste isolation pilot plant in New Mexico, which has had a few problems recently, but which has certainly

the capacity to absorb a lot of nuclear waste, literally, from all over the world. And it does encompass it, and that geological repository has been shown to be probably the most stable on earth. It has had no geological movement for 450,000 years.

Now, the people that say that's not enough, I don't know what to say. (Laughter) We've heard from Yucca Mountain. We had to have a hundred years. Then, we had to have a thousand years. Then we had to have 10,000 years. But those are two great facilities, if we'd just get on and do the job.

MS. DEWAN: And just one other quick piece. Sorry, about the nuclear waste. So, the video mentioned the 270,000 metric tons. And so, that's a large amount in terms of mass, but in terms of volume, it's an amount that would fit into a football field at about shoulder height. So, it's very, very dense material. So, just to -- as my engineering factoid (Laughter) that I feel the need to throw out here.

MR. EBINGER: It's a good one (Laughter).

MR. LEVINE: Okay. We've got five minutes left, so what I'm going to do is -- we've got three questions. We've got a fourth one, too (Laughter). I'm going to take them all at the same time, and we'll do this. So, first you.

SPEAKER: Alexander (Inaudible) for the U.S. Patent Trademark Office. You touched on this earlier, that there's a lot of bad PR surrounding nuclear. But I feel like a lot of anti-nuclear groups like Greenpeace are able to prey on that misconception, and like how a lot of people like, where factories are being designed, you have a lot of resistance at Town Hall meetings that you know, increase the cost and (Inaudible) and stuff like that.

So, I was wondering if there's anything being done by the NRC or the nuclear community as a whole? I'm just trying to educate regular people in the United

States about the benefits of nuclear, and also, to dispel misconceptions like that another Chernobyl could happen in the back yard.

SPEAKER: I think Charlie mentioned some concern in India about conventional reactors and water consumption. So, I was wondering if the advanced nuclear people are -- if there's any hope if making inroads with countries that have major water problems. India, countries in Africa.

MR. LEVINE: Okay. Sir?

SPEAKER: And I'm Jim (Inaudible) from Greenpeace (Laughter). And I don't mean to bother you, but I would like to press you on cost. Do you have a cost per kilowatt hour number?

MS. DEWAN: So, our cost to --

MR. LEVINE: Wait, wait, wait.

MS. DEWAN: Oh, sorry (Laughter). I thought that was the question.

MR. LEVINE: And then, there's one person right here.

SPEAKER: Yes. I was a meeting, actually, a couple of weeks ago about (Inaudible) reactors and (Inaudible) reactors, and they mentioned that (Inaudible) reactors to replace the (Inaudible) used (Inaudible) -- certification (Inaudible) use, whatever that may be in the near future.

But in the meantime, is there a potential for (Inaudible) to be exported as a proving ground for (Inaudible) why it's produced in the U.S..

MR. LEVINE: Okay, so Leslie, why don't you go ahead, since you already started on this gentleman's question.

MS. DEWAN: Oh yeah, I can do the cost number. So, nuclear's generation cost, the cost per kilowatt hour is always fairly cheap. So, like on the order of

three cents per kilowatt hour, though that depends a lot on what lifetime extensions you get for the plant in total. So, that's assuming a 40 year lifetime.

The big -- like the sticking point for a lot of nuclear facilities nowadays is the up front capital cost for building the plant. So, the cost per kilowatt electric that you produce. So now, for nuclear, they can be, say, $6,000 per kilowatt production.

So, we're aiming -- the external estimates that we've gotten from an outside -- EPC put us at $3,000 per kilowatt there. But that still is -- if you look at natural gas costs, they're 1,600 per kilowatt. So, we're not at the point yet where we can compete with natural gas.

MR. LEVINE: Okay, Leslie, since you're -- do you want to go ahead and take the last question, which involved the export of U.S. technology first? Right? This is the idea? Yeah.

MS. DEWAN: Sorry. If you wouldn't mind restating it. I apparently (Laughter) can only keep half the thing in my head at one time. Sorry about that.

SPEAKER: No problem. Since this technology, like you said (Inaudible) -- is there potential to export this technology as an almost proving ground to countries with perhaps, less bureaucratic regulations that would get in the way?

MS. DEWAN: So, there are a lot of regulations surrounding export of nuclear technology, especially with the Part 810 regulations. We found this out when we wanted to hire a Canadian intern, and found out it would be felony for us (Laughter) to tell this Canadian non-technical -- or non -- yeah. That was interesting.

So, we got all the necessary certifications in place to be able to talk to generally authorized countries, like Canadians. We actually have been talking with Canada, in particular about this. There are a number of countries -- like China, for

example, is harder to export to. Singapore now, is a little bit harder to export, even the technical information to.

But there is the possibility for strong collaboration with other countries, though no matter what, for a proving ground type of thing, you want to export it -- you'd want to do a prototype in a country that already has an established nuclear regulatory system in place, because otherwise, it's just -- yeah, it could end very poorly if you don't (Laughter).

MR. LEVINE: Okay. We've got two minutes. Charlie, quickly, the question, can advanced nuclear power help countries like India with their water problems?

MR. EBINGER: I think it can, although it is a big problem. They are looking massively at -- it's not the best way to go, but they're looking massively at desalination as one possibility. Just mentioned in passing, India, when we're talking about advanced reactors, is also very interested in doing lots of research on the thorium fuel cycle, because they have vast thorium reserves, as does Brazil, also looking at thorium. But most people I talk to aren't real big on thorium (Laughter). You would know more about that than I do.

MR. LEVINE: Okay, and --

MS. DEWAN: It could have a lot of potential in the future (Laughter).

MR. LEVINE: Okay, finally, one last question. Josh, you can take this, if it's okay.

MR. FREED: Sure.

MR. LEVINE: Anything the NRC has done or can do to educate, dispel --

MR. FREED: Well, look, I mean --

MR. LEVINE: -- some of the (Inaudible) that have been on it.

MR. FREED: I mean, the NRC's mission is to regulate and ensure the safety of reactors, and I think they've actually done a very good job at that, if you look at the safety of American reactors over the last 40 or 50 years. I think there are pockets where there is concern, still, about nuclear.

Actually, the closer you get to an existing nuclear facility in many cases, the more support there is for it. And it's also generational. And we're seeing the younger the people are, and we're talking 35 to 40 and under, the more support there is for nuclear, and the more support there is for nuclear as a solution to climate change.

So, I think frankly, it's still very much a concern, but it's addressing itself, thanks to new reactor technologies and concerns about issues like climate and comfort with technology.

MR. LEVINE: All right. Okay. We're all done. Let's thank the panel (Applause) and feel free to come up and talk to us.

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