Webinar transcript

The promise and potential of micro-reactors
The NICE Future Initiative offered this webinar on 23 March 2019. It can be viewed at www.youtube.com/watch?v=OBP7CbGmC0s. For more information, see nice-future.org/webinars.

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About the transcript
Because this transcript was created using transcription software, its content might not precisely represent the webinar.

Jordan

Hello, everyone. I'm Jordan Cox, and welcome to today's webinar, which is hosted by the National Renewable Energy Laboratory. Today's webinar is focused on the promise and potential of microreactors. Before we begin, I'll quickly go over some of the webinar features. For audio, you have two options. You may either listen through your computer or over your telephone. If you choose to listen through your computer, please select the "Mic and Speakers" option in the Audio pane. If you choose to dial in by phone, please select the "Telephone" option, and a box on the right side will display the telephone number and audio PIN you should use to dial in. If anyone is having any technical difficulties with the webinar, you may contact the GoToWebinar's Help Desk at the number shown on your screen. If you'd like to ask a question, we ask that use the "Questions" pane where you may type in your question. Also, I want to emphasize that the recording of today's presentation will be added to YouTube, and the link will be provided to you through your e-mail that you can watch at any time once it's been uploaded. Today's webinar agenda is centered around a presentation and panel discussion from our expert speakers on providing insights into the paradigm-shifting potential of innovative designs, new and exciting uses, and the timeline to deployment of microreactors. Before we get going, I want to say a quick, "Thank you" to all of our panelists who have joined us, and we have a very big panel today, so, I want to say a quick "Thank you" as well to all of our expert organizers. The admin and support who have helped with this webinar have made this possible, so, thank you. In just a second, we will have our first panelist introduce
the webinar, but first, we are going to have a brief introduction of a Nice Future Initiative by Giulia Bisconti.

Giulia Bisconti is a senior advisor with the Office of Nuclear Energy at the United States Department of Energy and Lead Countries Team member for the NICE Future Initiative. Giulia, do you want to go ahead?

**Giulia**

Thank you, Jordan. Hi, everybody. I'm one of the members of the Nice Future team and I'd like to extend a warm welcome to everyone on behalf of the Nice Future Initiative Lead Countries Team—that’s the United States, Canada, and Japan—and our participant countries—Argentina, Poland, Romania, Russia, UAE, and United Kingdom. Being a part of the Clean Energy Ministerial—or CEM—is still new for the Nice Future Initiative. The Nice Future Initiative was formally launched last spring in Copenhagen in the presence of ministers.

We will next be convening ministers in May 2019 in Vancouver, Canada. Stay tuned for high level announcements related to the ministerial by checking www.cleanenergyministerial.org. The initiative is off to a strong start and puts, for the very first time, the spotlight at CEM on nuclear and high-level discussions about clean energy systems. Our Nice Future events have engaged a wide network of colleagues from 26 countries. Our events have also had collaboration or interest for more than 80 organizations—this includes government, multi-government organization, academia, industry, and NGO organizations—including environmental NGOs—groups supporting engagement of women and millennials, and non-nuclear stakeholders from the renewable sector.

The Nice Future Initiative engages all these clean energy supporters in new conversations about nuclear energy and opportunities for innovative nuclear to advance clean energy goals. The individual considers the many roles that nuclear energy can play in future clean energy systems, including complimenting renewable energy and ensures that policy makers around the world have information on the whole set of clean energy options. So, today, we are delighted to focus on one important and exciting topic of the Nice Future Initiative—microreactors. Microreactors have tremendous paradigm-shifting potential, as Jordan mentioned, and are one of the technologies to watch as part of clean energy systems design of the not-so-distant future. Our webinar's focused on specific topics that are part of the Nice Future vision.

We want to share different country angles and experiences. To those who are participating on today's webinar, we invite your webinar—or other suggestions—to Jordan Cox at NREL. Again, that's Jordan.Cox@NREL.gov. If you like today's webinar, please spread the word. So, to close this intro, let me say we are excited with today's experts and very much thank David Blee at the Nuclear Industry Council for proposing and co-organizing this webinar. Thank you, Jordan.

**Jordan**

Thank you so much for that introduction, Giulia. So, in a moment, we'll hear from our first speaker who will give an introduction to the webinar, and that's David Blee. David Blee serves the president and chief executive officer of the U.S. Nuclear Industry Council, the leading business consortium advocate for nuclear energy and the promotion of the American supply chain globally. After David Blee's introduction, we will hear from Shane Johnson. Shane Johnson is the deputy assistant secretary for Reactor Fleet and Advanced Reactor Deployment at the Office of Nuclear Energy in the United States Department of Energy.

Along with Mister Johnson, we will also hear from Jeffrey Merrifield. Jeffrey Merrifield is a partner and energy section leader at Pillsbury Winthrop Shaw and Pittman law firm. After Jeffrey, we welcome Christina Back to the webinar. Christina Back is the vice president of nuclear technologies and materials at General Atomics. And finally, we will have Doctor Shannon Quinn. Doctor Quinn is vice president of science, technology, and commercial oversight at CNL's nuclear science and technology projects and
programs for the government of Canada, as well as commercial S&P projects and programs for third-party customers. With that, I will welcome David Blee to the webinar.

David

Okay. It's great. We really appreciate the cooperation of the NREL, the quickly growing Nice Future team, and, of course, our all-star experts panel from North America. And this is a very dynamic and promising and very, very important topic. In terms of—by the way, I understand this is a record turnout for the webinar series.

We're delighted to hear that and look forward to the Vancouver meetings as well that Giulia talked about. As we look at the panoply of microreactors issues or challenges in terms of the future and the promise and potential, we certainly do that against the backdrop that certainly growing [Break in audio] global demand, [Break in audio] and nuclear technologies across the board. We certainly have—why isn't that going forward? Hang on for a second. Okay.

Challenges worldwide—escalating global water stress throughout the world. And we have also a growing demand for electrification as evidence here by this slide on the electric vehicle penetration in the market globally. So, given those many challenges and certainly, growing demand and growing electrification and the growing need for clean energy, we are fortunate that nuclear energy innovation's on the march and the future of nuclear energy is now, as was opined by Georgia Power this past week where they put the crown on the Plant Vogile Expansion, which was a capstone moment for the first AP-1000 dome. In terms of other technology, we have some enhanced SMR deployment on the horizon with NuScale's Small Modular Reactor closing in on NRC approval and other promising advanced reactor designs progressing into North America. Moreover, you have microreactors as sort of the latest manifestation of what we're calling a new era of nuclear innovation enlightenment, with myriad applications for global demand that we'll hear about here shortly.

Obviously one—economical clean energy replacement for diesel generation, off-grid flexibility, and versatility including a nexus with renewable systems and industrial applications, emergency response to name a few. So, for the next 25-30 minutes or so, we're gonna delve into this and we will see [break in audio] are a game changer with respect to enhanced economics, factory assembly, versatility, advanced safety and security. So, with that, I look forward to our panel and to the question/answer session to follow.

Jordan

Thank you so much for that introduction. We'll now hear from Shane Johnson.

Shane

Thank you, Jordan. My name is Shane Johnson. I'm the Deputy Assistant Secretary for Reactor Fleet and Advanced Reactor Deployment in the Office of Nuclear Energy at the U.S. Department of Energy. The Office of Nuclear Energy is the department's civilian nuclear energy organization and we're really focused on three key areas with respect to the development and deployment of nuclear energy technology. Those are supporting the existing fleet of commercial light water reactors that are in operation in the United States, the development and deployment of an advanced reactor pipeline for future reactors—those reactors being both light water reactor technologies as well as non-water advanced reactor technologies and fuel cycle infrastructure related to the development and deployment of new fuel cycles in support of advanced reactors.

Nuclear energy technologies have reliably and economically produced about 20 per cent of the electrical generation in the United States over the last two decades and nuclear energy remains the single largest contributor of non-greenhouse gas emitting electricity generation in the U.S. This represents about 60 per cent of the non-greenhouse gas emitting electricity generation in the U.S. The Department of Energy
looks across the spectrum of advanced nuclear technologies that are either in deployment or undergoing commercialization and look at it from the size comparison of its electrical output. And we’ve basically thinned the suite of nuclear reactors across these five categories—full size reactors, which represent 92 of the U.S. operating reactors in the range of something greater than 600 megawatt electric to 1600 megawatt electric; mid-size reactors—of which there are 6 operating in the United States currently—those range in size greater than 300 megawatt up to 600 megawatt electric; small modular reactors—we are characterizing those as something greater than 50 megawatt electric up to 300, and we currently have, as David pointed out, NuScale Power has their advanced small-modular reactor under licensing review by the U.S. Nuclear Regulatory Commission, where they’re seeking a design certification, which we are encouraged that that will be coming in the not-too-distant future.

The fourth category we see are very small modular reactors and those range from something greater than 10 megawatt electric up to 50 megawatt, and several of the advance reactor non-water technologies that the department is currently partnering with industry and the development would fall under this category of very small modular reactors. And then, lastly, the microreactors—the topic of conversation for this webinar. Microreactors, the department sees, as a class of very small reactors targeted for non-conventional nuclear markets, including remote sites, remote communities, mining sites, backup generation—possibly for nuclear power plants—and other industrial applications. Such applications face economic and energy security challenges that could be uniquely addressed by these innovative microreactor designs. Generally, microreactors are differentiated from the other classes of reactors by features such as factory fabrication, transportability by truck, rail, and simplicity of design features—particularly those related to reactor control and safety.

The department is very enthusiastic about the potential for microreactors to provide the industrial sector with clean, reliable, and resilient energy supply. These higher temperature enhanced safety and longer operating concepts are capable of electricity generation, district heating, industrial process heat, water desalination and purification, as well as hydrogen production. It is the department’s view that microreactors can provide remote communities in industrial applications with reliable electricity at competitive prices compared to current costly diesel generated markets. They also provide resilient and reliable energy supplies and provide a source of clean and reliable electricity during disaster and emergency relief operation. Based upon feedback from U.S. industry, the department is undertaking key research development and demonstration activities in support of the commercialization of microreactors.

The microreactor technologies are really based on reactor technologies that have been under development for a long time and we’re leveraging historic research and technology that’s been developed by the department and industry for non-light water reactors. Our research and development activities in support of microreactor commercialization has been focused principally in the areas of semi-autonomous and autonomous control systems coupled with remote monitoring capabilities, improved materials, and advanced manufacturing methods to reduce system cost and increase performance of the microreactors, as well as the development of approved transportation containers to aid in the deployment and the retrieval of microreactors from remote locations. The department has also been working with industry on the demonstration of microreactors before commercial deployment. We’ve been engaged by a couple industrial concerns looking to use our existing capabilities at the Idaho National Laboratory for testing microreactor technologies and concepts as well as the demonstrating an entire working reactor before it is put into commercial use. The department is aggressively working to establish an inventory of fuel to support these near-term demonstration efforts.

Microreactor designs are expected to be fueled with high assay, low enriched uranium, and the availability of this material on the microreactor development timeline is currently limited. The department has several efforts under way to make this material available on the timeline and scheduled that the microreactor vendors are looking for in terms of supporting their demonstrations before commercialization. The department has also been supporting a new approach to licensing advanced reactors, including microreactors, through our licensing modernization project, which is a DOE industry cost-share effort to establish a technology-inclusive risk-informed and performance-based approach to
licensing. The U.S. Nuclear Regulatory Commission has developed a draft regulatory guidance based on this approach. And, just recently, the NRC's advisory committee on reactor safeguards has recommended the commission adopt this approach for non-light water reactor technology.

The department’s been engaging with the private sector through private/public partnerships in accelerating advanced nuclear technology development, including microreactors. We have funding opportunity announcement that is open and available for industry solicit funding from the U.S. government based on their reactor technology needs—whether it is from a licensing support to technical support to working with our national lab [Break in audio]. We're also engaged through our national laboratories and the nation's University of Nuclear Energy Training programs to provide those technical support to industry as well as developing the pipeline of talent that is gonna be needed to push these technologies through commercialization and into long-term operation. And with that, I'll return the webinar back to Jordan.

**Jordan**

Thank you so much for that, Shane. Now, we'll hear from Jeffery Merrifield.

**Jeffery**

Jordan, thank you very much. Let me pull up my presentation here. Again, as was mentioned, this is Jeff Merrifield. I’m a partner and energy section leader for Pillsbury law firm and pleased to be here today to talk about the current state of what’s going on with nuclear power.

[Crosstalk]

**Jordan**

I’ll just quickly jump in. It looks like you're in the "Presenter Mode" for your presentation so it’s kind of giving this dual screen view. If you could maybe back out of that and jump into the full screen mode, that would be great. Thank you.

**Jeffrey**

Okay. That is a good question as to how to do that. Let me deal _____. I apologize. Sometimes technology is...

**Jordan**

No worries. We are just gonna quickly take back control over here and if you could select "Monitor 2" when you so your presentation select, I think that might help. But we'll see what happens.

**Jeffrey**

Tell you what—why don't—you guys have a version of the slides. Can you pull those up?

**Jordan**

Yes. Of course. We'll get right on that. Bringing those up.

**Jeffrey**

Actually, I pulled up Monitor 2. Can you see that now?

**Jordan**

One second. We are just working through it.
Jeffrey

Sorry about that. Well, folks, I apologize for the technical issue here. I’m actually—

Jordan

Not an issue. Go ahead and select Monitor 2 from the drop down. I think we just sent control of the presentation back to you.

Jeffrey

Okay. Yeah. I’m trying to figure out how to—

Jordan

No worries. We have your slides pulled up now. We’ll bring it back to our screen and show your slides for you.

Jeffrey

Okay. Why don’t you go to slide two, please? All right. Great. Sorry for the technical problem here.

Really, where I wanted to talk about was sort of where it all began and how we got to the opportunities for microreactors today and it really goes back to the individual on the right, Hyman Rickover, head of our Navy nuclear program, who really initiated two things—one being the Nautilus, which was the first nuclear ship under sail; the second, on the bottom was Shippingport Atomic Power Station in Pennsylvania, which really came as a development of that entire Navy program. The reason I start here is that, well, for the most part, all of the reactors around the world are light water reactors. Many of the advanced reactors and small module reactors we’re gonna talk about today are not light water reactors. Some are, but many of them are not. And there are many developments that we’ve had in the U.S. over the years where these technologies have been deployed, but certainly not as familiar to some on the line.

Go to the next slide, please. There are, in fact, many innovative ways that nuclear reactors were deployed in the ’60s and ’70s. If you look on the left-hand side—for those of you who may not be familiar with it, the first nuclear reactor that we put down in Antarctica was to provide 1.8 megawatts of power for McMurdo Sound. So, this is one of the first ways of generating power for the operations of the team who we deployed around 24/7 operations in Antarctica and that was used for several decades as a reliable source of that power. That was a 1.8 megawatt reactor and actually, this is the first modular reactor. That was built in a series of 200,000-pound modules that were built and then shipped and installed in Antarctica.

On the upper right-hand side, the closest nuclear plant to Washington D.C. was actually less than 20 miles south at Fort Belvoir. This was the SM-1 reactor of 2 megawatts operated by the U.S. Army. And if you actually flew over Fort Belvoir today, you can see what that reactor is. It's still there. It is to be decommissioned.

On the lower right-hand side, one that is not as familiar to folks—the Sturgis. This was a converted World War II Liberty ship that had a 10-megawatt reactor installed. Both of those two were operated by the U.S. Army. In the case of the Sturgis, it was deployed to Panama Canal for the purpose of powering several watts at the Canal for, again, about a decade and a half. So, a variety of what would now be considered microreactors deployed by the U.S. government and successfully demonstrating their capability of placing these reactors into service.

Next slide, please. But, you know, a lot of the innovations that we're taking advantage of today were actually established by the Atomic Energy Commission decades ago. On the left was Peach Bottom Unit 1. This was a high-temperature gas reactor produced by General Atomics that you used TRISO fuel in a hexagonal form. That led to several other designs that evolved from there, but really was the roots
of many of the principles that we established in the U.S. behind temperature gas reactors that will be certainly tapped into for future micro and larger advanced reactors that are proposed to be deployed over the course of the next 10 years.

Similarly, EBR 1, which is a Fast Breeder Reactor, placed in Idaho—this was actually some of the first power that was produced in Arco, Idaho—sort of a very famous story of the first four light bulbs being powered by energy coming from this particular reactor that operated successfully for over a decade and then, subsequently was replaced by EBR 2, which has successfully run for a very long period of time. Finally, on the lower right, in Tennessee at Oakridge—the Molten Salt Reactor Experiment—7.4 megawatts, also demonstrating the success of Molten Salt technologies. For the most part, many of these designs, because of the prominence of light water reactors, were set aside with a lot of promise in developments that occurred during the '60s and '70s. Next slide.

Looking at the opportunities, it has been talked about before—the importance of nuclear power in both U.S. and international carbon-free generation—certainly, advanced reactors and microreactors can play into that. As mentioned, microreactors typically are the 1 to 10-megawatt range and, to add to some of the comments that Shane made, many of these designs are planned for load following and certainly will be complimentary to renewable deployment that has already occurred here in the United States. They're small footprint ease of use allows for a number—additional deployment activities. Again, many of these conceptualized, backed by the Atomic Energy Commission decades ago. Next slide.

In terms of where we stand today, there are a large number of advanced nuclear reactor developers—Third Way, I think, tanked here in Washington. It's postulated that there could be at least 50 or perhaps as many as 70 advanced reactor designs being deployed, significant support by the U.S. Congress last year—$1.46 billion for the office of nuclear energy. And a series of developers—we've had some discussions already about NuScale—I would mention X-Energy, which is the developer of a high temperature gas reactor used in the pebble technology, was a recent recipient of a $4.5 million DOE grant to focus on the production of those TRISO particle fuels you can see in the right-hand side. Terrestrial Energy, a leading molten salt reactor developer, has received three GAIN grants for its design and that has been produced in parallel both in the United States and Canada. GE/Hitachi's Prism—that obviously is not a micro. That is a large fast reactor, but one which has been selected for the virtual test reactor deployment in Idaho.

And then, finally, Oklo, which is a microreactor, has been very active in some involvement with the NRC—my former agency—and they are actively moving towards conducting—having the NRC conducting design review and are working on near-term deployment options in the context of the next three to five years. Next slide. As was mentioned, there are a lot of opportunities beyond base load power. On the upper left-hand side, you'll see a picture of diesel generator in tank form in Alaska. There are—if you look at this, a large number of those were used in remote villages in Alaska.

It requires the importation of very large amounts of diesel or importation, but in transporting large amounts of diesel up to these locations. That can cause some localized air issues. It can also be an issue if you have particular weather conditions that make it difficult to bring that fuel in. So, the benefit of being able to tap into the 24/7 multiyear technologies provided by microreactors, is certainly quite exciting. Other uses—now, I have on the upper right-hand side, one of the world's larger desalinization plants, but certainly, in remote parts of the world, there are areas which do not have access to clean, fresh water and microreactors can certainly provide that type of technology to those people who need it.

Finally, there are heat and power opportunities in a variety of petrochemical facilities worldwide. The use of clean nuclear energy to microreactors could provide an important benefit not only from a clean air standpoint, but certainly, from the clean energy standpoint. Next slide. And with that, I want to wrap up and thank all of you and look forward to any questions you may have.
Jordan

Thank you so much, Jeff. And now, we welcome Doctor Christina Back, and to both Doctor Christina Back and Doctor Quinn, I think, at the beginning, I messed up your titles just a little bit, so, please feel free to correct those. We are very grateful to have you and want to make sure those are correct. But with that, I'll turn it over to you Doctor Back.

Christina

Okay. Let's see. Do I have the screen there? Okay. I'll try and go pretty quickly through here so that we can maybe make up a little time so there's time for questions.

I'm very pleased to be speaking here. I was asked to really give a talk about the technical considerations developing microreactors, so, this will be a little bit different and I'll try and go into where the technologies and the innovation and how it relates to nuclear energy sources really comes in. So, I'll start with a little overview and then, go into some places where we think the technology and innovation can change our future. So, first, I just want to give an overview of the basic components of a nuclear reactor so that you can see exactly where the innovation can be happening here. So, you know, basically, you have fuel.

It generates the heat. The cooling transfers the energy from the fuel to the turbine. The turbine converts the heat to the mechanical energy, and a generator finally converts it into electrical energy. So, you can see on the right there the inside of what Jeff Merrifield showed, which is the vessel of the Shippingport reactor. So, you can see the size there and that picture, as you can see dated, by how the people look there. That's from 1956.

And so, the point here is that these four basic components are in any nuclear reactor—whether it be one gigawatt or one megawatt. And so, let's just look a little bit more at that. Let's see. My "Advance" button is not advancing. There we go.

So, if you look at a large power plant—this is Diablo Canyon in California—and on the bottom right there, you can see the turbine generator hall. And I put a little green bar there, which is actually right next to a person standing there, but he's a little bit small, so, I just wanted to point out a size to give you an idea of how big these generator halls are for these turbines. Now, when you look at technology—if you look at Shippingport, for instance, the transfer medium was water and so, that water needs to be turned into steam. That steam then drives the turbine. And for a one gigawatt or 1,000-megawatt plant, it gets quite big, as you can see.

So, now, with the understanding of nuclear energy, today's new science and new engineering, now, we can really design reactors for the application. And so, if we look at now the kind of power level that we're talking about for microreactors, 1 megawatt is about 1,000 houses. So, small modular reactors can be smaller. In fact, an advanced reactor for a 1-gigawatt size, from designs that we have at Genera Atomic, can be about half the area that a typical plant takes up now.

So, as you can see, for small modular reactors and for micro, that's a much smaller footprint. And there's some things in the ______ plant that do not scale, but you can see that there can be a huge savings in terms of the size of the plant. So, in the next few graphs here, I just go into some of the microreactor characteristics from the point of view of a 1 to 10-megawatt plant. So, obviously, you have to be safe. So, "defense in depth" means that you have multiple layers of safety—there are typically three.

We would still retain that in a microreactor. And passively safe has become more and more understood and important as we go forward in the future. So, the new designs really focus on a compact reactor core to make sure we achieve this passive safety and still provide the power, albeit at a lower total power. The transportable nature is so that it can be taken to places where, for instances, there are hurricanes or natural disasters where you might need electricity very quickly in a populated area or in very remote
areas, as has already been discussed. So, part of the transportable is that you want to have a very
straightforward installation.

So, that doesn't need to be the number of years that you would take for a large plant, because much of
this, as you can see at the bottom, would be modular and factory built. So, there's an advantage there in
terms of being able to control the cost of the fabrication, not just in terms of size, but also in terms of
security and safety. And finally, we've already talked about the power being less than 10 megawatts
electric, and that also enables you to be load following and matching with renewables, for instance. So,
if we look at a reactor designed for the purpose, a compact reactor core is going to need the following
things that I have listed here, and I'll just talk about them very briefly.

Many of the designs go to higher density fuel or higher enriched fuel allows you to get in a smaller
volume a sufficient amount of fuel so that you can achieve the chain reaction and the fission reaction so
that you can generate the energy. The next two there—the new and safer fuel rods—refers to the kinds
of new materials that we use—for instance, as a stepping stone. You can think about the accident
tolerant fuel that's being deployed—or that is soon to be deployed—for light water reactors. Those are
different kinds of metals like FeCrAl or ceramics—like, silicon carbine composites. These have different
properties and interactions with the coolant.

In the light water reactor case. It's water, but in an advance reactor, that could be a different coolant. As
you can see, I list there below, non-water coolants which are like helium, molten salt, sodium, and lead-
bismuth. And that's in recognition of the fact, as Jeff Merrifield pointed out in the Shippingport—I didn't
go through that fully since he talked about it already—but the important point there is when you're
designing a naval reactor, you have a lot of water around. But when you design a microreactor, well, you
may be landlocked. You may not have the advantage of having a large body of water.

So, that's why these non-water coolants make siting much more flexible and there are many advantages
because, for instance, these coolants don't go through a phase change in the same way that water does,
which is part of what contributes to the problems that we had at Fukushima. Another important part is
advanced engineering of manufacturing methods. Can you still hear me?

Jordon

Sorry about that. There was a little technical difficulty.

Christina

Yeah. Okay. So, the manufacturing methods—you know, you probably heard things like 3D printing—
those kinds of things are started to be applied to reactor components. Now, in terms of power
generation, that's kind of the second half of an equation. And here, for small microreactor, you can be
smaller and much nimble, and that's what allows you to be able to load follow much more easily—
because there's less just physical inertia of the turbine, for instance, to get it spinning and follow the
baseload energy as it changes with renewables coming on and off the grid.

And, of course, that's controlled. And if it seems like that's not very interesting, I'll just given an example
of natural gas plants, and you can see here that there's continuous innovation that has happened in, for
instance, natural gas. Light water reactors have been around for over 30 years and there are many
technologies that we can take advantage of in the same way that natural gas plants are doing here. So,
of the two key enablers you see there—the advanced high temperature and the advance manufacturing—
and since 2000, they have gained efficiency of up to 22 per cent.

That would be huge to employ those kinds of advantages in a nuclear reactor today. So, I just want to
give some now, overview, and this is taken as an example from EM2 just for simplicity, because it lists
out kind of all the different areas that you can make innovation and advantages. So, in this half, it's kind
of the heat generation that I talked about. So, you can see there's the convert and burn physics that has
to do with how long your reactor can last. The typical microreactors can go from three years or longer
There are different reflector materials you can use to make the core more efficient at retaining those neutrons inside, keep the fission reacting going. High density fuels, as has already been talked about—uranium carbide, uranium nitride—those have more uranium per volume, as well as being able to increase the enrichment. And then, you have some things like silicon composite cladding, which are new cladding materials. The second half is kind of the power generation side, and you can see here the things that could be employed in an advanced reactor—high temperatures, gas turbines, variable speed, permanent magnet generators, frequency inverters, dry cooling, et cetera. So, I just wanted to give you a flavor of the kind of technologies that can be brought to bear to really bring the nuclear industry into the 21st century and enable small microreactors to be built.

So, with that, I'll leave you with questions and any comments. Thanks.

Jordan

Thank you so much, Doctor Back. And now, we will hear from our final speaker, Doctor Quinn.

Shannon

Hello and thank you very much. If you bear with me, I'll present my screen. So, for the sake of time, I will, I think, be able to progress quite quickly through my slides because my topic today is really sort of Canada's view of SMRs, which would include the full range, including right down to microreactors. But, as I have the advantage of going last, I also have the advantage of seeing that the Canada's position and strategic approach is quite well-aligned with that of the U.S., and I think the audience will be able to see that. What I will say now is very consistent with what we've heard from Christina, Jeff, and Shane so far, and so, what I'll try to do is actually sort of point out where the similarities exist and maybe where there are some sort of slight differences that maybe we can all leverage for our respective advantage.

So, like the U.S., Canada has a long history in nuclear energy, dating all the way back to World War II and our linkages to the Manhattan project. Where we diverge a little bit in nuclear history is that then, following World War II, Canada made a very conscious effort to pursue only civil applications—nuclear energy—for really power and medical purposes as opposed to weapons purposes. So, we are the only tier one nuclear nation that is not a weapons nation, which puts our areas of technical expertise just a—places them a little bit differently than some of the other countries, but it puts us in a world where I think we can probably work with others to leverage our respective technical advantages in the area of nuclear.

So, one of the other things that I'll mention is that, like the U.S., we have a very strong nuclear regulator and regulatory regime. What is maybe a little bit different in Canada is that our nuclear regulator, the CNSD, takes a non-prescriptive approach and so, while in Canada today we have heavy water reactor technology deployed, the regulatory regime is not really specifically tailored to that, but is built generically on the concept of being able to prove a safety case.

And so, from that perspective, it's quite well suited to being able to, from a regulatory point of view, consider new and novel technologies, which is one of the important aspects of being able to ultimately get some of these new and advanced reactor concepts to market. And so, really, in Canada then, because we do have a long history of developing reactor technology, it does position us well, alongside our nuclear regulator, as being able to look at some of these advanced technologies and ultimately, help the private sector bring these technologies to market, because we do recognize here in Canada that the nuclear industry has changed quite a lot over the last many years and the rule of government, in particular, has changed. So, today, it really is a global commercial market, one dominated by private sector entities and not one dominated by governments, which is as it should be. And so, what we see going forward is that the—in Canada, we see the private sector leading this push into new and advanced reactor technologies and, of course, governments—at all levels of government—have a role to play, but they are not the leaders. They play an enabling role.

So, in Canada, we see that the SMR market is very ripe for Canada to take advantage, and really, in two different roles—both as a buyer and an incubator. So, in Canada, we see that we have many remote
communities. There are 200 off-grid communities across Canada, as well as a significant mining and oil and gas market that is off-grid, and all of these have potential to be interested buyers. But we also have, as I said, an environment where we have a hub and an incubator to help the private sector bring these technologies to market, which is actually very similar to what we heard from Shane earlier in terms of the U.S. DOE's approach to bringing to bear some of its expertise as well as some of its U.S. DOE's sights to work with the private sector. So, what I can say is that in Canada, we've—together with CNL, we've—put quite a lot of effort into trying to understand the market and specifically, the market's interest in Canada, and we've had considerable interest.

So, dating back to 2017 when there were 80 responses from a variety of stakeholders to a market survey all the way to today, where we have, with CNL, a formal invitation process to site a demonstration reactor out at an EACL site—in that first go around, there were four applications received. And I'll skip, really, for the sake of time, right up to kind of where we are today in terms of CNL's invitation process and that is to say that there are various private sector companies working their way through the particular processes set up so that these different companies can work at their own pace. And what we see is that their Starcore and Terrestrial have passed stage one and invited to apply to stage two. And then, we have Global First Power passing stage two and moving into its stage three, which really just goes to show that there's a broad market interest in demonstrating, I would say, in North America, broadly speaking. So, Canada also went through a broader engagement where it looked at all levels of governance, our various utilities, and territories to put forward a road map.

So, I would invite people who are interested to look at those—at that road map. It is available online and it has findings across four pillars. And what really came out was that there is real opportunity for SMRs, yes, in Canada, but we think across North America and importantly, as a global market, and that SMRs really can compete with other electricity generating options. But one of the things that maybe I would like to reinforce—it's already been mentioned by some of the other speakers—is that SMRs also have an opportunity to work alongside other electricity generating options, particularly intermittent renewables such as solar and wind. But we do think that time is of the essence here, because there are climate change drivers that are creating an urgency and, in fact, there are many companies and countries, outside of North America, that are aggressively pursuing this. And so, the window of opportunity really is now if North American companies are to gain a certain competitive advantage in what we think is a global commercial market. So, thank you very much.

**Jordan**

Thank you so much for your presentation. I'll quickly say, "Thank you" to all of our panelists. We are now in the question and answer section of this webinar and we received so many great questions. I want to just quickly note that we won't have time to get through all of the questions 'cause we received so many of them, but we will do our best to reach out to our expert panelists and try to get the answers back to you. So, we have them written down, we have them recorded, and we want to just thank everyone who submitted a question.

So, in the question/answer session, the first question that I think we'll start with comes from multiple webinar attendees, is about the role of the Nice Future Initiative in all of the things that our panelists have discussed. The Nice Future Initiative is an international collaboration effort, and so, I guess, what is your—to all of our panelists—all of our panelists are welcome to reply to this—what is your view of the role of international collaborations and initiatives like the Nice Future Initiative and others in nuclear technology?

**Christina**

Well, this is Tina Back. I'll start off since there's a little gap there. You know, I think that all of these challenges are tough problems and we should really all work together and try and move the whole industry forward. So, international collaborations, I think, are important where they make sense, and
this is a global issue not just the United States or Canada. So, overall, I think it's important to be collaborative.

Jeffery

Yeah. This is Jeff Merrifield. I agree with Tina and I would add—I think what Nice really represents is a swing in the view toward how we engage in the use of energy technologies, both to enrich lives, spur economies. We're also doing it—do it in a way which is clean and respectful of obviously, the environment and the planet. I think, for a long time, a lot of folks who were very in favor of the introduction of renewables and power storage to address those issues and who were concerned about global climate change really were focusing more on those technologies than looking at the bigger picture of how can we use available resources, including nuclear, to effectuate those goals in a more holistic way?

And so, I think the Nice initiative has done a great job of re-focusing that to say, "Hey, listen—today, 35 per cent of the world's certainly comes from nuclear. How do we further enable these nuclear technologies in such a way to both provide more power and energy for economic growth and development in the third world and elsewhere, but do so in a way that really takes advantage of nuclear's clean generation portfolio?" And I think the discussion today has really brought out that convergence of how that policy initiative, undertaken through Nice, combined with the developments in both microreactors and advanced reactors, really gives us a springboard for full use of these technologies going forward.

Shannon

It's Shannon, and I think I would entirely agree with what's been said and maybe, just to say it slightly differently, it's been Canada's experience that in order to move towards clean energy across the board, it does take all forms of energy generation. And so, while nuclear has to be cost competitive with the other forms, it doesn't mean it's in direct competition. And, in fact, we think it takes all of them working together. Part of the challenge that we've seen—at least in Canada—is that the nuclear conversation tends to happen within the nuclear community, and one of the things that the Nice Future does as part of the broader clean energy ministerial is it brings the nuclear discussion into the broader discussion on clean energy with all of our colleagues across all of the different forms of energy generation, which is where we think it's properly placed so that we can look to all of our energy colleagues to come with ideas on how all of the different forms of generation can be brought to bear to solve some of the climate change issues.

Jordan

Thank you very much for all those thoughtful responses. So, we are coming up on the end of the webinar and we had a lot of questions that kind of all revolved around one issue, and so, I guess we'll summarize it with this for all of our panelists—what are some of the unique safety concerns and safety advantages of microreactors and why do you feel particularly confident that microreactors can overcome those in ways that maybe previous reactor technologies have left people worried or concerned about nuclear?

Jeffery

Well, this is Jeff Merrifield. I guess, as a former regulator, I'll take the first crack at that one. I think one of the—obviously, if we're using these in more remote areas, there are some where maybe the concern's—are we really fully cognoscente of these designs and how they can be used? And I think the answer to that is, "Yes." I think those who are developing these microreactors recognize that.

Those safety and security features are intended to be built into the designs. Some of them will be placed below ground; some of them will be designed and manufactured in such a way to make a very secure and robust system that can be operated. I think the other advantage of these reactors is obviously, the
amount of material is fairly small. And so, for that reason, even if there were an issue with the design in
terms of some kind of an operational concern, the amount of radiation that is contained is quite small
and thus would not have significant impacts on the local community. So, a lot of very beneficial aspects
to these designs, which regulators, like the Canadian Nuclear Safety Commission and the Nuclear
Regulatory Commission will look at very closely before they issue licenses for their approval.

**Jordan**

Thank you so much for that. And we are pretty much out of time, so, does anyone have any final
thoughts that they would like to use to wrap up some of the conversations we've had today?

**Christina**

Yeah. This is Tina. I'd just like to reinforce that we're really at the threshold of being able to use the
science that we've learned over the last 30 years about how to fabricate material even atom by atom and
really, how to engineer things to be safe and to be more efficient. I mean, if you just look at planes, you
know, we had the bi-plane, then, we had planes made out of metal and now, we're making planes out of
carbon composite. So, this technology can also evolve [Break in audio] and be as efficient and safe.

**Jordan**

Thank you so much and one more "Thank you" to all of our experts and our attendees for your
participation in this webinar. We very much appreciate your time and, in return, hope that there were
some valuable insights you can take back to your ministries, departments, and organizations. Please,
enjoy the rest of the day and we hope to see you again at Nice Future events. This concludes
our webinar.