KASIA KORNECKI:
Hello and welcome everyone to the report Briefing Webinar for the National Academies Report laying the foundation for new and advanced nuclear reactors in the United States. I'm Kasia Kornecki, the study director here at the National Academies, and I'll be moderating today's discussion. The National Academies of Sciences, Engineering, and Medicine are private, nonprofit institutions that provide independent advice to the nation on pressing science issues. For each of our studies. Committee members are chosen for their expertise and experience, and they serve pro bono to carry out the study's statement of task. Additionally, the report went through a rigorous peer review process and represents the consensus view of the committee. Before we start the briefing today, I'd like to introduce the president of the National Academy of Engineering, Dr John Anderson, to say a few words. Dr Anderson.

JOHN ANDERSON:
Thank you, Kasia, and good afternoon. Welcome to this briefing on our newest consensus study report laying the foundation for new and advanced nuclear reactors in the United States. As we transition to greater use of low-carbon energy sources to combat climate change, the need to consider all power sources is paramount. The primary goal of this study was to complete a technical assessment of new and advanced reactors, which have the potential to be smaller, safer, less expensive to build, and better integrated with the modern grid. Equally important was the need to identify challenges associated with commercialization and deployment of these reactors. It is especially timely report due to the important role new and advanced reactors may play in meeting energy demands in the future. I would like to extend a special thank you to the members of the Report Committee and to the briefing team for their tireless work. I would also like to thank members and staff of the Board on Energy and Environmental Systems, the Division on Engineering and Physical Sciences, the Nuclear and Radiation Studies Board, and the Division on Earth and Life Sciences for their unwavering dedication.

And to everyone attending this webinar today, thank you for your interest. The National Academy of Engineering, as part of the National Academies of Sciences, Engineering, and Medicine, is committed to providing expert, unbiased engineering leadership and insights on topics of great importance to our nation and the world. Completing studies such as this enable NAE to fulfill its mission. Again, thank you for your interest and I hope you enjoy today's briefing. Back to you, Kasia.

KASIA KORNECKI:
Thank you, John. I'd now like to introduce the committee members that we have on the line with us today. We have Dr Richard Meserve, the committee chair, who will be presenting the briefing shortly. In support, we have Dr Michael Corradini Dr Michael Ford, Dr Ahmed Abdulla, Dr Jaquelin Cochran, and Dr Todd Allen. At any time during the webinar, you can submit questions for our speakers using the Q&A form, which is embedded below the webcast. You can also explore our digital interactive report summary and download the full report by going to nationalacademies.org/advanced-nuclear. And with that, I would like to now turn things over to Dr Meserve for the briefing. Dr Meserve.

RICHARD MESERVE:
Thank you, Kasia and John, and good afternoon to all of you. Welcome to our webinar. Can I have a next slide? The fundamental question that we were asked to respond is what will it take for new advanced reactors to play a role in a low-carbon future? And we have a two years of work by the committee to address this question. And as you see, we have covered a lot of territory in our work. Next slide. Let me

set the context. We have 92 nuclear power reactors in the United States, soon to have 94 as the Vogtle 3 and 4 reactors in Georgia come online. They're actually quite old. The average age of the nuclear reactors in the United States is 40 years. Most of the fleet of reactors has been given a license renewal that allows them to continue to operate for 60 years in a handful. I think it's actually about 16 have either obtained or are seeking a subsequent license extension that would allow operation for 80 years. They really have been the workhorse of our power system and that is see, they currently provide about 18% of our electricity in the country, about half of our low carbon electricity.

But there isn't much interest among generating companies about further construction of these large gigawatt-scale plants. Part of the reason, of course, is that natural gas is proven to be comparatively cheap, very cheap in the United States. And so there's an economic advantage that natural gas has. But beyond that, the unfortunate reality is we haven't built a nuclear power plants in the United States beyond our efforts to construct them at the Vogel and summer sites and the summer plants were canceled because of the cost growth. And the Vogel reactors have come online, but with really a doubling of the estimated cost in their coming in about seven years later than anticipated. So it's proven to be a extraordinarily challenging investment for generating company. In fact, given that the Vogel plants are gonna cost about $31 billion, it's been sort of a bet your company proposition to imagine constructing a gigawatt scale plant in the United States, given the recent experience, which I must say is not unique to the United States, the same problems are occurring with these large plants that are being built now in Europe.

But there is interest among many of the generating companies in exploring the opportunities for reactors of different types, particularly small modular reactors. So the unit costs will be considerably less than the vendors of those reactors claim that they will be cost per kilowatt, much less offer safety advantages and as we'll discuss other advantages as well. Next slide. Of course, part of the justification for this study is anticipation that the demand for electricity over the coming decades is going to grow. We show in this slide various estimates of what that growth could be, and you'll see the growth demand of electricity extends across our economy from transportation to residential use, industrial use, and commercial applications. Next slide. This study it's been indicated reflects great interest and importance of the subject matter. It is sponsored by a Dr James Truchard, who's a member of the National Academy of Sciences, and by DOE's Office of Nuclear Energy. We have already produced a workshop proceedings which is available on the Academy website that has to do with the societal acceptance of nuclear power.

There is this consensus report which we're briefing today, and we anticipate there'll be a follow-on workshop that will occur later this year. Next slide. On the left side of this slide, you can see the intent was to cover nearly all the subjects that bear on the role that advanced reactors could play over the coming decades. And they arranged, of course, from the technical through economic, national security workforce, the whole range of issues. There's one important area that is not within the scope of this study, and that has to do with the fuel cycle. We do not discuss issues associated with the modern fuels that some of these reactors are proposing to use in particular. There's a lot of interest in high-assay, low-enriched uranium, which is not currently available in large quantities in the United States. And we don't deal with the waste problems, which are very substantial and need to be addressed. And the reason we don't is that there was a counterpart study that was undertaken by the academies.

It was completed towards the end of last year and you can see a link at the bottom of the page where you can get the companion report that deals with these very important fuel cycle issues. Next slide. This shows the committee. As you know, several of the members of the committee are on the line today. It shows the various organizations which are associated and have experiences across the wide range of issues that we've confronted in this study. You can find it as an appendix to the report biographies of all the committee members. Next slide. As in the case of all Academy studies, extensive effort to have meetings at which we collected information from a variety of different sources is revealed on this slide. The information about our public meetings is available on the National Academy website, along with recordings of the public parts of these meetings. So the background that we received is available in large part to you. Next slide. I think the fundamental lesson we'd like to have you take away from this webinar is there is a whole range of issues that need to be confronted.

If advanced reactors are to play a significant role in contributing to our response to the need for a low-carbon future, we discuss all of them. And our fundamental theme or prefigure it now is that we urge that these issues be addressed now in a timely way so that we can provide the opportunity for advanced nuclear reactors to contribute in a major way. Next slide. This is a sketch of the timeline. There are a variety of advanced reactors in various stages of technical maturity. We see that some of these new reactors are gonna be demonstrated in the early 2030s and some will be later. We don't know exactly when they're gonna come into widespread commercial use that could expect to occur in the 2030s and no doubt, as the need for the decarbonization of our economy goes forward over the years, there'll be further demands that nuclear reactors can be used for purposes other than just electricity, and exactly when nuclear reactors will contribute in a significant way is very uncertain. It depends on technical factors, depends on not only in the nuclear side, but on the other technologies that could contribute to low-carbon future.

Depends very significantly on the economic issues and how we compare with costs and a variety of other regulatory, legal, social, and other policy issues that will impact the exact trajectory we undertake to deal with the total modification of our energy system. Next slide. This slide just reveals a variety of the areas in which we see the need for action taken in order to provide a role for advanced nuclear. We'll be walking through various of these issues as we go forward in this briefing. And they're treated much more extensively, of course, in the report. Next slide. I have not said what we're talking about with regard to advanced nuclear reactors other than they aren't gigawatt-scale plants of the type we currently rely. And the answer is, is we're counting as advanced reactors, everything other than the existing large light water reactors of the type that are currently the backbone of our electricity system. They range from small modular light water reactors that is obviously built on, it's an evolution from current technology sodium-cooled fast reactors.

High-temperature gas reactors are also of reasonable maturity, as well as other technologies that are of great interest in vendors include molten salt reactors and gas fast reactors. Including even in the molten salt category, some reactors where the fuel is actually dissolved in the molten salt rather than being separated from it. Each of these technologies offers different aspects. There's different challenges, presumably, and eventually we'll have different technical solutions and different economic impacts, and applications. Next slide. We do have a recommendation that does I think cut across all of these reactors. I mentioned earlier that there are a fuel issues that need to be confronted. So there are some novel fuels, and that's the subject matter of the adjacent report that I mentioned. There are also materials issues. You've talked, for example, about advanced alloys. You look at the alloys that are qualified for use in nuclear facilities. We're talking about alloys that were developed 35 to 100 years ago.

There are many other alloys that have been developed that promise to have greater improved performance at high temperatures, greater radiation resistance, greater corrosion resistance, they're in commercial applications, some of them, but they haven't been qualified for use in nuclear plants. We see some advantages in trying to push forward to get some of these advanced materials qualified for nuclear applications and that there is an opportunity to do this and we have some suggestions about how to speed that process along. It offers both safety advantages and possible economic advantages because the stronger materials could be thinner and have improved thermal properties. Thank you. Next slide.

LECTURER:
We have a lot of discussion in our report about the very important activities that are underway at the Department of Energy. And there are several different programs that they're on advanced reactors and dealing with the various issues associated with them. One of the very important programs is the Advanced Reactor Demonstration Program. That's a program where two of the designs, the ones that are of the closest technical maturity, are receiving funding jointly with the vendors to proceed with demonstrations, and those include a sodium fast reactor and a and a gas reactor. There were a series of other designs that are in sort of a queue that are receiving much less funding right now, but allowing them to proceed. We have a real challenge here and there are a variety of very interesting technologies, as I've noted, are very different maturity of different characteristics, perhaps different economics, different advantages. And we see the need for the DOE to develop a more structured program in order to sort out how to proceed with these designs.

So we suggest having stage milestones so that each of the designs as they develop are measured against their technical advancement, cost issues, regulatory issues, social acceptance issues, and for plants that don't meet the milestones, they should be dropped from the program and others that could be added to the queue to proceed on to demonstrations. The reason we suggest this is that there isn't gonna be enough money within DOE to pay for all of these reactors to proceed through the demonstration phase. And we need to have a thoughtful and structured and fair program that provides an opportunity for funding so that at the end of the day, the reactors that are the most socially acceptable, economically acceptable, are given the chance to proceed. Next slide. Of course, having some demonstrations completed isn't gonna complete the task, we need to go from a handful of demonstrations to wide scale deployment, if we have the impact that's necessary. So we recommend that there be evaluation of incentives that are available now through the Inflation Reduction Act to see if they're sufficient to allow the commercialization of these reactors to proceed.

I mean, the hard fact is, if we're going to change our whole energy economy, trillions of dollars are gonna be necessary. That means we're gonna have to tap into traditional debt and equity markets, that means that the risk has to be reduced, the financial risk among all the other risks needs to be reduced sufficiently so that there'll be investors in them. Now that incentives that could be provided that are discussed within the Inflation Reduction Act include, of course, various tax incentives or loan guarantee prospects from DOE, and those need to be evaluated to see whether they are sufficient to proceed. We're talking about a subsidization of these developments that are like those that have been made available for renewables and which have had very effective in driving down the costs and making them more widely available. So we think the same sort of investment is necessary in order to allow advanced reactors to contribute meaningfully in the shorter-term, and that may not be until the 2030s when they start to contribute, but if we're gonna reach our carbon goals, we need to get moving on these issues.

Next slide. There is interest in applications beyond just electricity production. Of course, that if we're going to achieve our decarbonisation goals, we need to penetrate into other sectors. And that in particular, for example, the industrial sector that need to replace the use of fossil fuels as a source of heat. There's great interest in the prospect that nuclear energy could play a role in that, not just for producing electric power, but also providing the necessary heat for industrial processes. The advanced reactors offer some opportunities 'cause many of them operate at higher temperatures than existing reactors, and so they can provide the high value heat that is necessary for some of these applications. And we think one of the important early applications might be for hydrogen production. Advanced reactors would provide the opportunity for providing both the high temperature heat and the electricity that be necessary for the, for example, the solid oxide electrolysers. So there is an opportunity that could well be exploited by advanced reactors that extend well beyond electricity generation.

Next slide. This is the slide that just indicates the origins of the overnight cost for existing LWRs. So what's striking about this slide is the fact that about 40% to 50% of the cost is in the civil works, only 10% to 20% is for what we call the nuclear part of the plant. Now, it may well be for advanced reactors that this allocation of cost could be quite different, that the smaller reactors and any which could be built in a factory perhaps, or certainly large components would be built in the factory. The need for lesser onsite work that may be necessary other than these gigawatt scale plants. So the allocations are gonna likely be different. But nonetheless, the civil work should be seen as a likely to be a meaningful part of the cost. Next slide. So we see the opportunity here to deal in a more significant way with addressing the capital, excuse me, the construction costs associated with these reactors. If you look at the DOE program, there's, you know, many hundreds of millions of dollars being spent on technology for the nuclear island and a relatively small amount of money that's being spent on the civil works that's directly associated with nuclear facilities.

So we see the opportunities that are there for dealing with a significant component of the cost by more research to be done to bring onto line advanced construction technology hopefully to bring down costs associated with the introduction of plants. Next slide. Now, one of the... we have a whole chapter, chapter six that deals with the management challenge that's presented by construction of a nuclear facility. The reality is that the generating companies have no particular reason and no justification for maintaining the skilled staff to be able to monitor and evaluate, and basically ride-herd over the construction of a reactor or their other projects. They tend to rely on contractors, consultants to various (INAUDIBLE) to come in and provide them with advice, ideally informed advice, but the danger is, is they don't have skin in the game, they don't bear the risk that the generating company does. And there is a challenge that they may well be optimism bias, just the assumption that everything's gonna work out, the likelihood that the contingencies get burned through without very careful evaluation of the impacts.

So we strongly urge the creation of some sort of a structure so that there is a capacity to those who are gonna be supervised on the construction bear more of the risk that could be pursued by way of a joint venture among a variety of nuclear generating companies that are generating companies interested in pursuing those. So they have a skilled staff that could build a variety or a number of plants and could have experienced learning curve experience as a result of that capacity. So at the least, they may be relationships with the engineering, procurement and construction firms that are responsible for this, that they have stakes in the game as well. Next slide. Beyond that, there are workforce challenges. And these range everywhere from the craft workers through the PhDs that you need to satisfy stringent quality assurance requirements and all nuclear construction. And we need to have trained and skilled workers to be able to fulfill that obligation. So we have a recommendation for work to close the gaps that we already see and having the skilled workers to be able to complete the necessary tasks.

And that maybe not only in the construction companies, but in operating companies and the regulators as well. Next slide. Chapter seven deals with regulatory requirements. It's of course understandable that the existing NRC requirements are focused on light water reactors. That's what the NRC regulates, and so directly is made up of light water reactors. The advanced reactors, particularly those that use different coolants in the water reactor, present very different regulatory issues. And beyond that, certain design elements and terms of applications, for example, passive safety, basically, the safety issues are likely to be different. In some cases, they may be more difficult, the issues that haven't had to be addressed, sodium reactors, for example, one has to worry about sodium-air, sodium-water interactions. That would not be an issue with light water plants. We see the need for providing money that is available to the NRC to build capacity to be able to deal with significant differences that exist between advanced reactors and the light water reactors are accustomed to dealing with.

The NRC is confronting this now. They have a regulatory proposal (INAUDIBLE) that's been presented to the Commission for initial evaluation, that is for a technology independent performance-based risk-informed regulatory system. And beyond that, the NRC is actually processing interactions with various other vendors by providing guidance through technical reports and white papers, processing of exemption requests and so forth, develop the regulatory guidance the vendors need. But these sort of one offs that are being dealt with in the way of the specific to each vendor don't provide the necessary guidance for the entirety of those like to pursue advanced reactors. So we see the need to put regulatory requirements in place because one is gonna invest in an advanced reactor with one of these to understand the regulatory environment within which it has to operate. We have a particular recommendation as an example of that with regard to siting an emergency planning zone. There is some that contemplate that you might use an advanced reactor to replace an existing fossil plant that provides the opportunity that could be existing infrastructure, you know, the transmission facilities, cooling of labor force that's accustomed to working in a power plant, communities that are used to having power plants in the area, that that could be an impractical opportunity, but it may not be possible, don't have the siting an emergency planning zone guidance that's available for.

Beyond that, if you're gonna use reactors in the vicinity of industrial facilities, you need to look at the safety impacts of each facility on the other. So it's an area where developing regulations and providing guidance is gonna be essential for the vendors to be able to develop their business plans and to know what deployment opportunities are available too. Next slide. One of the important areas in chapter eight of our report deals with this important issue of societal acceptance. This slide sort of flags a variety of the issues which we identify as best practices for community engagement, and we strongly urge that the generating companies apply these best practices receding, and would include getting a consent-based process in site selection, to make sure that the community is fully engaged and appreciates and welcomes the facility release, doesn't oppose (INAUDIBLE). The danger is that this could be something that imposes costs, it could be difficult. It could have resolved, of course, in some sites being... the community saying they don't wanna have a nuclear plant, in which case they shouldn't go there.

The Yucca Mountain experience reveals the challenge if you don't have a consent-based process to proceed with nuclear activity in. So we strongly recommend pursuit of best practices regard to societal acceptance. Next slide. This is our recommendation on that point. We flagged the fact that additional time and financial resources are likely to be necessary for this. But at the end of the day, it's probably an essential ingredient for a successful plant and we'll save costs at the end. Next slide. The discussion I had earlier about regulatory requirements dealt principally with the safety-related issues. Of course, the NRC also regulates security. And there are...

SPEAKER:
There is an opportunity as one designs advanced reactors to consider the security implications right in the design. I was the chairman during the period around 911, and we imposed very substantial obligations on the licensees that required new capital equipment. And there have been substantial increases in the operating costs because of the need for a very capable security force. There are opportunities in designing the reactors to build those in right from the beginning, which not only can improve security but potentially can greatly reduce the total cost of cumulative cost over time. But in order to have this occur, you need to have very clear guidance from the NRC about what is going to be required and how. The staff has proposed the rule for the NRC's consideration. That this opens the door for new ways of thinking about security. We welcome that. But the guidance needs to be put in place and rule needs to be put in place so the vendors can take the opportunity to actually apply. Next slide.

Now, the subject of our report deals with usage of reactors within the United States. But international marketing is likely to be very important as well. Many of the vendors, as indicated contemplate the factory construction of the reactor or significant components of the reactor. In order to justify the establishment of the factory, you're likely to require a large number of orders, and they may not be a sufficient book. It's available from the United States to be able to justify a reactor. So, international opportunities and exports may well be important for the. Important advantages of factory construction could actually occur. But in order to have that happen, we need to develop customers. There's a lot of interest in reactors in Southeast Asia and Africa. Many of those countries have no experience with nuclear facilities recently, (INAUDIBLE) and there's a need to develop infrastructure in those countries. Not only the technical infrastructure but the societal infrastructure, regulatory and legal infrastructure.

So, we strongly urge the United States develop a plan to enhance the capacity of these foreign countries to implement reactors in a way that is safe, secure, and meets the nonproliferation requirements. But in order to facilitate this, It's also likely. It's gonna be necessary that there be financing that's available. The Russians and the Chinese are. The Russians have built about half the reactors around the world today. And the Chinese are very interested in spending their exports. The Russians subsidize their plants. They have a reason for doing that. So, if they build the plants, they're likely to have a continuing role with the company that, the country that acquires their plants over time, and the plant will need skilled consultants, it will need fuel, need parts, and components. So, there's an opportunity to be engaged with that country over perhaps 100-year life of the plant. And so, it's a critical infrastructure for a country. So, that they see a foreign policy of pursuing this.

I'm sure the Chinese, who have similar interests in building infrastructure around the world because of the foreign policy influence, the results are likely to be intense competitors for international business. I think a lot of these countries would like to build from the United States. We don't put the same kinds of pressures on them. But in order for that to occur, we need to have a financing package that is attractive. And we (INAUDIBLE) executive branch to work on this to enable this to proceed. We see broader benefits of this as well as if the United States is to have a significant international law in defining the ground law and the safety, security, and safe criteria. It's important that we be part of the game. And so, our international engagement serves a broader purposes that benefit all of us. (UNKNOWN) next slide. Well, this has been a lightning race through the report. These are the various areas flagged as being ones that are important. All of them are important if we're gonna have advanced reactors, be a significant contributor.

Next slide. So, we see. And this is our real bottom line. There's a need for sustained effort and robust financial support by the Congress, federal agencies, the nuclear industry, and the financial community. If advanced reactors are to play a meaningful role in providing us with a low-carbon future. There are many challenges to be overcome. And as I prefigured at the beginning if we're. If the advanced reactors. To play a role, we need to confront those challenges soon and deal with them. And so, we highly recommend that we take a broad look at all the things that need to be done. Next slide. Well, I'm going to now ask if some of my colleagues who helped prepare this report would like to supplement my comments, and then we'll turn to questions. Let me add that I've highlighted just a handful of the recommendations from the report. And the full report covers a much broader territory than I've described. And we urge you to review the report because there are many other aspects that you may find of interest.

But let me invite other members of the committee to see if they'd like to supplement my remarks at all. I'm not seeing any hands, so let me invite questions. I think (UNKNOWN) is gonna be the umpire here? Yes. Alright. Thank you for that great presentation. We're going to do the Q&A portion of the webinar now. So, as a reminder to folks who are watching, you can submit your questions using the Q&A form that's embedded below the webcast window. And we have a lot of participants watching today. So, we may not be able to field all of these questions, but we will try to get as, get through as many as we can. So, first question to get us started, and I think this was already touched on in the presentation, but maybe we can expand a little bit. How does the United States compare to other countries in the development of advanced nuclear technologies? And is there an opportunity for the US to lead in this field? Let me say there is great interest in advanced reactors around the world, greater in some places than in others.

I think my sense is that in the United States and Canada in particular, the variety of vendors are very interested in proceeding. We have aggressive programs in the Department of Energy to sort of nurture them and going forward. So, think across the full range of technologies were among the leading countries. The Chinese have a variety of reactors that they're also pursuing, and they are, as I've indicated, greatly interested in their international competitiveness. The Russians have experienced with many of these reactors, including the sodium reactors, for example. So, I think that we are among the leaders in the country in this area. And is. The fact of the matter is that we have very aggressive programs through the Department of Energy to advance these technologies. Anyone have anything to add to that? Otherwise, we'll move to the next question. Todd has his end up. Todd go ahead. And think I just wanna supplement what you said (INAUDIBLE). I think the US, more than any other country is approaching advanced nuclear and a lot of different applications.

But it's not just technologies. It's where it will be deployed. And I also think the US is ahead of other countries in developing new support programs. You mentioned ARDP in the government to support that commercial industry. So, I think in that sense, we are ahead of other countries. And to your point about sort of keeping the foot on the accelerator, I think that's important because we have that definitely. Thank you Todd. Mike. And just pile on from Todd's comment and say that the other areas in scales and use cases. So, there's been a lot of effort put into looking at microreactors and use cases for those as well as small modular reactors that you mentioned in your comments. And (INAUDIBLE) use cases that move beyond into advanced fuels and use in industrial process has been a significant emphasis in the research side for the US. I guess I should have said also in passing that, although we don't find generating companies in the US that are particularly interested in gigawatt-scale plants.

That isn't necessarily true in many other foreign countries. So that they may be interested in things that are not advanced reactors that are of interest elsewhere. Mike Courtney, do you have anything to add? Just that there's a couple examples that I wanted to point out. For example, the Canadians have identified an advanced light water reactor technology by General Electric that they're going to try to situate at Darlington and in Saskatchewan. That's been announced. And in Eastern Europe, a couple of the countries have approached NuScale for considering building their designs in Eastern Europe. So, those are a couple examples where international markets can grow and, or have to be considered. Great. Thanks, everyone. OK. So, for the next question. Can you say more about the operating cost of these newer designs? At what price could they produce and sell electricity such that they are viable investments? Can these designs drive down the price of electricity in the market or just fill the demand gap?

And to this, I'll add an additional question that's related. Do you foresee the generation of electricity using nuclear power becoming as cheap as it is to generate electricity today using photovoltaics? Well, let me just say that anyone who's making the estimates about what it's actually gonna cost to produce electricity from these power plants, it's got to have a whole series of embedded assumptions. There's a lot of uncertainty because the developments need to occur. There's a whole series of these issues that I've mentioned that need to be resolved. So, we don't have a. We cannot project with confidence what the cost per kilowatt, for example, of various these designs will be. The vendors have their estimates that they have articulated remains to be seen whether those will be achieved. The fact of the matter is, is that the cost from electricity from photovoltaics and wind has been going down. But there is, many of the studies show there's a need for firm power as well. And that the cost of the whole system is less if you have renewables that are supplemented by some other source that provides firm power.

And that's described pretty extensively in chapter three of our report. And so, that the cost per kilowatt is not really very complete metric to be able to judge the plants because they serve different purposes. And so, we see the possibility, for example, that advanced reactors may provide the necessary firm power or part of the time to back up renewables when it's needed. But also could be the power is not needed for the grid. That power could be used for other purposes, particularly for industrial purposes such as hydrogen generation. So, there are other applications that come on that provide a role. We do have some. Again, this uncertainty associated with all the models. We think that nuclear power could be competitive in the market, it costed like $4,000 per kilowatt. But a lot depends on what the competition is and the availability. And it could well be that there are constraints on the other technologies that open up opportunities for nuclear at higher costs, say $5,000 per Kilowatt.

And of course, there are these special applications that may be particularly suited for nuclear that provide opportunities. So, it's a complicated picture at the moment. Great. Thanks, (UNKNOWN). Is there anyone else that wants to add to that? Or should we move on? We'll move on. Alright. In terms of citing, based on local popularity, what incentives do you expect to need for citing, or rather, what aspects of advanced reactor operations might be viewed as beneficial to communities in an environment where permitting is such an obstacle to all resource development in the US? Because every technology that's of significant change that can confront problems of societal acceptance. That's not a problem just for nuclear. (INAUDIBLE) to siping transmission lines, for example, has been hugely problematic. I think that there's not likely to be some standardized set of rules and what exactly a local community is gonna be interested in. And that it's gonna have to take a lot of controversial, the conversation with the affected community to realize exactly what their concerns are and how best to confront them.

Advanced reactors might be attractive because of the fact that the vendors certainly are making claims about increased safety. They're smaller

RICHARD MESERVE:
So that they may take up less land area, for example. But they're likely to be less conspicuous in that there may be below grade. I mean, I think there will be a need for the vendor, the generating company to have an extensive interaction with the community to appreciate exactly what their concerns are, to try to address those concerns if they can. And ideally, over time you build a capacity to communicate and build trust that provides an opportunity for this to be a win-win for both the local community and for the vendor and generating company. Ahmed spent a lot of time on this issue and let me turn to him to make some comments on the societal acceptance issues.

AHMED ABDULLA:
Yes, thank you very much. I definitely agree with this notion that all infrastructure faces problems. And in chapter eight for our report, we take a considerable length of time to go through the reasons that are inherent to nuclear reasons that are broadly applicable to all technologies. I would say in any case regardless of your technology or the type of reactor you are citing, the cost of building an infrastructure for effective honest two-way communication might seem high at the front end of the project, but if the project ends up failing because of public opposition, it's gonna be much more costly for developers in the long run to ignore that key element. And so we go to great lengths in the report and the recommendation that was highlighted made that obvious to ensure that developers really understand the importance of building that infrastructure for communicating.

RICHARD MESERVE:
I see that Mike Cordani had his hand up earlier and I see Mike Ford does now. Let me turn to you first, Mike, Mike Cordani and then to Mike Ford.

MIKE CORDINI:
The only example I was gonna add to what Ahmed said is that I wanna give some specific examples. For example, TerraPower is looking to cite its first demonstration plant as a replacement for a coal plant in the Pacific Northwest area. So you might find certain communities interested for what they wanna replace the current technology with, and nuclear might be an appropriate possibility.

RICHARD MESERVE:
Mike Ford.

MICHAEL FORD:
I was just going to point out that there's actually been some work done in this area that we cite in the report related to Department of Energy Investment in citing a tool that can be used by the industry to

help them locate areas that might be amenable to citing. And so there's a recognition and understanding that this community engagement needs to happen and there's tools being put out there that help industry do that. And so it's not just left to them to search for that. They're actually things that the Department of Energy has funded. There's one called the Stand Tool that's on the National Reactor Innovation Center website that people can access to look for those kind of things.

RICHARD MESERVE:
There's a recent report on consent-based citing that the (INAUDIBLE) has just issued. Todd. Todd

TODD RANDALL ALLEN:
Something that I just add on to what Ahmed said is we were very careful to say, don't wait to engage the community at the point where you're ready to site, right? It's continuous, right? You should think about it from when you're starting to design things, will it make a difference? To when you cite through operating the plan and maintaining that relationship with the community.

KASIA KORNECKI:
Great. Thanks, everyone. So next question, I'm going to combine two questions again. So would the DOD procurement approach, which is to buy a fleet of some early units be useful rather than relying on the 1Z2Z approach, but that's used by DOE ARDP to garner real cost gains. A supply chain needs to see ten, 12, 20 units on order like DOD aircraft to gear up, correct? And then related question, can the committee comment on the potential role that DOD versus DOE could play in accelerating the demonstration and commercialization of advanced reactor technologies given their outstanding experience, for example, the Navy and current appetite for use of nuclear energy?

RICHARD MESERVE:
Oh, let me say that we have a energy system in the United States where we have a series of private companies are the source for generating electric power for the most part. Some of them may have some municipal generating companies and so forth. But basically, this is the private sector that's responsible for this. It's not one entity that's buying the fleet as the DOD is to meet a wide range, the full scope of what they need, for example, fleet of submarines or aircraft carriers or aircraft, (INAUDIBLE). That isn't the way we proceed with basically the market for generating companies. So we do have a recommendation, however, that to get some of these benefits, at least through this idea of a joint venture among generating companies for the construction. Now that could extend all the way to their negotiations with the vendors so that it'd be a prospect to build a large number of reactors at one time from a particular vendor and get some opportunities for the vendor to put in a factory, for example, to proceed with that, an opportunity for the cause of a large number of units to get the cost per unit down and to have a skilled capacity among the generating companies to basically supervise the construction.

So there's a way to get at least part of those advantages if one of our recommendations were pursued. Now, we did have briefings. There is an effort that's underway by DOE on the development of an advanced reactor that the smaller advanced reactor (INAUDIBLE). It contemplates as project (INAUDIBLE). We did have briefing on that. So I`m aware that what they're doing, they have a different set of problems that they need to confront. They're talking about particular kind of application, which would not necessarily be the one that would be common among the commercial power companies. DOD might want a reactor they can drop in a place quickly that when the day or two , is producing power and then be able to pull it out, for example. There are some needs for emergency use more broadly that that same kind of design could be useful. But it's a very different regulatory system. DOE regulates its own reactors. So the (INAUDIBLE) would not be involved. There's a set of different issues in terms of the interaction with the public with regard to these reactors and how they're deployed and so forth.

So this would be very different circumstances. This scenario where I know that Mike Ford has experienced and I see his hand up. So let me ask him if he'd like to supplement my answer.

MICHAEL FORD:
(INAUDIBLE), you hit on a lot of the high points. I would say that it'll depend on what the use case is for the Department of Defense and to the extent that they have requirements that lead to a higher cost profile for those units, then they may not be beneficial in jumpstarting in a commercial manufacturing line that would take advantage of that. So it would depend on what the requirements are that the DOD placed in terms of the characteristics of those plants that they would buy in bulk. So could I see them doing that and helping jumpstart certain aspects or components that would might lead to a follow on unit that's a commercial unit? Perhaps that's a possibility. One area we do cite in the report, though, I will note that is an immediate thing that the DOD could do, which is to be a customer in a public-private, in a power purchase agreement, excuse me. And so there's always that possibility that they can purchase from a utility and work in an agreement for up to a 30-year for the case of the Department of Defense power purchase agreement that will help jumpstart in some of their larger installations.

And so that would be an immediate area that they could help in outside of buying their own fleet of reactors, which is always a possibility, but may or may not, depending on the requirements, lead to an actual commercially viable unit. It may, but it may not.

KASIA KORNECKI:
Right. Thanks, Mike. Next question. It seems other countries such as South Korea and China have taken advantage of the learning curve to significantly lower the cost of nuclear reactor construction. What is fundamentally different in the US versus Korea and China in terms of construction cost?

RICHARD MESERVE:
Well, my understanding is that in both countries they've been building a substantial number of units substantially contemporaneously. So you have the opportunity for people who build one reactor to then move on to build another reactor someplace else. You have the learning curve opportunities that are available and that they're building a whole series of reactors. So there are those opportunities that are available and have been available in those countries for learning curve, whereas the United States since we haven't built anything since the completion of the (INAUDIBLE) for about 40 years. So we don't have the same kind of skills that have been maintained to be able to do these sorts of construction. But let me say as well that the problems that we discussed with regard to the management of large projects are not unique to nuclear where we have had a problem with megaprojects of all kinds in the United States, and this is with highways and bridges and subways and all sorts of things that of the unfortunate characteristic of many of these projects are way over budget and much delayed.

And so we have a broader problem in this country. It's not just nuclear power plants that we need to learn how to build better and learn about how to do this more effectively, but it's the problem of megaprojects of all kinds. Mike Cordini has his hand up as well as Ahmed.

MIKE CORDINI:
So I just wanted to give a couple of examples. One example is the Japanese in 2000 and 2010 built something on the order of six to eight boiling water reactors and saw by continuing practicing their construction techniques, saw a reduction in cost of about 25%. Similarly, the Koreans, the South Koreans in building the Barakah site at UAE were following essentially their APR 1400 design for what they're building on-site in some of their other units back in South Korea. And then it has seen improved economics in the building and Barakah plant. So I think it's practicing makes perfect. And you see that particularly with South Korea or historically with the Japanese.

RICHARD MESERVE:
Ahmed.

AHMED ABDULLA:
I completely agree with the point about megaprojects. I think we struggle to do them worldwide. However, because we love examples, I'd like to add a couple. The French example was always taken to be this example of a radical scale of nuclear power. And it's only when the numbers came out in 2010 and people started analyzing them that they realised that despite the contemporaneous deployment costs actually went up. So we didn't have learning, we actually had negative learning as it were. So I would ask the questioner to be cautious with the numbers that come out. It'll take decades for us to get reliable numbers about plants that were built even ten years ago.

KASIA KORNECKI:
Great. Thanks, Ahmed. So we're coming near to the end of the hour, so I'll ask just one last question before we finish here today and that question is, if you were delivering the findings of a similar study done ten years ago or 20 years ago, what if anything would have been different from your conclusions today?

RICHARD MESERVE:
Well, actually I was involved in a study about ten years ago when precisely this point, it was America's energy future. And at the time, no one was thinking about construction of anything other than the large gigawatt scale reactor. And we said that at that time in that study that there was an opportunity to build two to four within the next eight or ten years. And whether there were gonna be more was highly dependent and whether we were able to meet budget and construction schedules, and we weren't able to do that. And so we don't have them. So we actually have an exact example of what we would have said ten years ago `cause we said it. And the world has changed in that there are opportunities for advanced reactors that have developed and ideas about them, their idea about the need to confront carbon change if any carbon problem has grown, consideration across the whole economy has grown. So there's a large number of issues that are quite different today than they were ten or 20 years ago.

And as the range of opportunities that are available, unfortunately, have also grown. But if we're to realize them, we need to move out and address them. Both Todd and Jacqueline have their hands up. Let me invite quick comments and we're gonna close down.

TODD RANDALL ALLEN:
Yep. I'd say really quickly, the existence of the commercial companies and all the different use cases were not there ten years ago. I think the way the government has restructured itself with things like

ARDP, were not there before and I don't think that we were talking about things like societal acceptance as being core to deployment. So I think a lot of things have changed.

RICHARD MESERVE:
Jaquelin.

JAQUELIN COCHRAN NREL:
I would also add that the electricity market context has changed a lot. So prices are a lot, like if we were decarbonizing ten to 20 years ago compared to then, there are many more options today that nuclear is competing against.

RICHARD MESERVE:
OK.

KASIA KORNECKI:
Great. Thank you. So with that, I think that's all the time we have for questions today. I'd like to take this opportunity to thank all of our speakers and the entire study committee for their work on this report. For more information, for everybody who's been watching, please visit Nationalacademies.org/advanced-nuclear. You can explore the report and the report resources. We will be posting this webinar recording later next week so everyone who's registered will get an email when the recording is available. And with that, thank you all so much for joining us and have a great rest of your day.