TRANSCRIPT

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Cindy Folkers: Moderator

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Our presenters will be Dr. Gregory B. Jaczko, former chair US Nuclear Regulatory Commission, Dr. Mark Z. Jacobson, Stanford University, and Dr. M.V. Ramana, University of British Columbia. The chat will be open for the duration of the briefing. Click on the chat icon on your zoom toolbar to open your chat box. We appreciate your hellos and comments in the chat. Make sure you send your message to everyone at the drop-down arrow so that we can all see your messages. We'll be using the Q&A box today for all questions. Click on the Q&A icon on your zoom menu to submit your questions. Please submit all questions to the Q&A box rather than the chat. You can submit questions at any time during and after the presentations. During our Q&A we'll do our best to answer as many questions as we can. We will also provide contact information to follow up on questions after the briefing has concluded. We are recording this webinar and will share a link to the recording in our follow up email, which will also include a link to the Google Drive folder for our congressional briefing with all of the PowerPoints being shared by our presenters today.

The Google Drive folder will also include informational videos and articles related to our briefing. Without further delay, it is my pleasure to introduce our first speaker, the Honorable Gregory B. Jaczko, who was chairman of the US nuclear regulatory commission from 2009 to 2012, and the commissioner from 2005 to 2009. Prior to that, he served as a congressional aide to Senator Harry Reid, and then Congressman Ed Markey. Currently Dr. Jaczko is a visiting lecturer at Princeton University and runs a clean energy development company. He authored *Confessions of a Rogue Nuclear Regulator*, Dr. Jaczko. Welcome.

Dr. Gregory Jaczko: Panelist

Thank you, everybody. It's an honor to talk to this group and to share my thoughts about nuclear power and climate change. I have some slides. There's a lot of information on these slides, and I promise I won't go through all the information. But as was said, the slides will be available if anybody wants to go through them in more detail. I think before we begin, since really the topic is nuclear power and US climate goals, I think it's important to really set the table for what those are. And I think this is an important milestone that gets to really the crux of the issue, which is what role can and should nuclear power play.

I just pulled a couple of key dates, but you know, really the key date in my mind that I keep coming back to is 2035 for electric-- for decarbonization in the electricity sector. That's certainly a stated goal, the Biden administration, it's also effectively the recent goal of the IPCC as when was announced recently. So, that gives you a sense of the kind of timeframe we have to really deal with the electricity sector, which is right now, where nuclear is primarily thought of as an asset. So because none of these electricity infrastructure assets are deployable in an instant, when we think about 2035 as a goal for decarbonization, that means we have to have an infrastructure in place, certainly by 2030, with meaningful large scale deployment in order to be really an entity that can contribute meaningfully to that 2035 goal.

That's a little bit of the framework for the discussion that I'll present. There seems to be—we appear to be in a time in which there is a lot of interest around this topic. I didn't give sources and citations for these. But these are all various headlines related to these issues of nuclear power and climate change. “America's warming to nuclear power” was about polling results. “American Support for Nuclear Energy, Highest in a Decade”, you can read all the headlines here. What's interesting is that not all of these come from the same time period. And a lot of what we're seeing today reminds me very much of what happened about 10 to 12 years ago when I was at the Nuclear Regulatory Commission.

You'll see here, in fact, everything on the left is from over a decade or more ago, and everything on the right is recent. We had a movie in 2013, Pandora's Promise, which basically made the promise that nuclear was going to be a solution for climate change and environmentalists needed to kind of come around and those issues. A similar movie came out about a decade later. And so, you know, what I'll talk about today is, in many ways, what happened in that earlier timeframe and where we are today, and what lessons, if any, that tells us about how I think this period will go going forward. I think it's important, again, to put in context.

And these aren't my words, this was an opinion piece that was published in 2015, by a number of energy and climate experts, James Hansen, among them, indicating what we need to do for nuclear be an element of climate change. And this is globally, and one of the statements they made is that we're looking at a total requirement of 115 reactors per year to 2050. And again, this was in 2015. And, you know, in their statement that nuclear will make the difference between the world missing crucial climate targets or achieving them.

Again, I think, just to set the table and put this context, in 2015, there were calls for hundreds of reactors to be built every year, maybe you could give them some slack and say it's 2023. Well, if we look at how we're doing, we're nowhere close to 115 reactors a year, we've certainly never done that in the history of, of the industry. It's certainly a monumental task for nuclear to be a major contributor in the climate flight.

Perhaps they'll be a minor contributor. And I think that's something that certainly we could talk about a little bit more. But, you know, I think at the face of it, you know, when we are talking about nuclear and climate change, there's a lot of challenges and difficulties with that as a solution.

The first and foremost is that we're simply not nor have we ever built reactors at a scale that really could contribute meaningfully. And of course, if you look in the last decade or so while we build a handful of reactors, or two handfuls of reactors every year, we've also had almost an equal number of reactors go offline. The net increase has been a handful every year. So obviously, things would need to change. And that's a lot of I think what the focus is right now is how can we change the policy paradigm, so that nuclear power can become a meaningful contributor. And what I want to talk about, again, is going back to that idea that you know, where we are today is where we were about 10 or 15 years ago, or even 20 years ago, where there was a tremendous effort and push to stimulate through policy, new reactor construction, because of the need to have nuclear power as part of a climate strategy. It wasn't as extreme of a need at the time as I think it is today, but it certainly was a significant discussion, certainly among nuclear proponents, about this idea of nuclear being a solution for climate change, and wanting significant policy to overcome these historical hurdles for large scale nuclear deployment, or at least, you know, certainly than that last 20 to 30 years.

What did we do?

Well, one of the first efforts was something called nuclear power 2010, which was the Department of Energy effort to basically test out the licensing process with the Nuclear Regulatory Commission, because much of the undertone for a lot of these issues is that regulations make it difficult to license reactors to build reactors and that's really what's been holding us back. In 2002, the Department of Energy started this program got significant funding to test out the NRC licensing process. Now I'll note that the original programmatic goals for that were to have orders from one or more nuclear power plants by 2005. In operation of new nuclear power plants by 2010, obviously, those goals were missed. Although, you know, one could argue perhaps that orders were in the pipeline for new reactors, but they probably wouldn't come to a little bit later. But there certainly were no plans in operation by 2010. And I'll go through in detail a little bit more focused on there.

The Energy Policy Act of 2005, was a significant stimulus for the industry, essentially address some of the main issues that the industry felt were challenges at the time. One was a risk insurance program to hedge against regulatory delays, production tax credit for these new and advanced reactors that was limited to a certain number of reactors, but certainly was a significant incentive for those reactors that were initial designs that were intended to be built first. And then federal loan guarantees, which was also very significant because of course, one of the challenges with large scale reactor builds is the concerns about financing costs and long construction times. Loan guarantees were a way to help reduce borrowing costs and quite frankly, in some cases, even allow borrowing, when there was a lot of skepticism about new reactors. And then in 2012, was the culmination of about four or five years or probably three years of effort on SMRs and strong SMR (small modular reactor) support program to the tune of about half a billion dollars over five years. And that was started in 2012. So just to give you a sense, and I'm not going to go through all of the details, I'll just skip to the bottom line, there were two key elements of nuclear power 2010.

I'll just say there are other federal programs as R&D programs, a number of things that have been done to support the industry, what I'm trying to focus on those things which were really designed to get reactors built and operating. One element of that was the nuclear power 2010 early site permit program, which was to support the process of using early site permits, which was an enhancement to the NRC regulatory process to facilitate licensing of reactors, three early site permits were supported to that program.

And three of those, they were all issued-- licenses were issued, or early site permits were issued for all of those generally in a reasonable timeframe. No reactors were built at any of those sites. It was largely, you know, a test of the process. But it determined the process could work, but no reactors came out of it. You can look at that as a success or failure, I suppose, depending on what you think the ultimate goal was. But again, if we look back to 2012, the goal was actually to get reactors built by 2010. A key element of that program as well was the nuclear power 2010 combined operating license support effort, which did wind up switching, if you will, to the to the winning horse in the race, which was the Vogtle that became really the lead license for a new reactor design. That license was ultimately issued in 2012, when I was at the Nuclear Regulatory Commission, and I'll talk a little bit about where that where that program wound up. But ultimately, no more than one of those COLs has ever turned into an actual construction at a reactor. And there were other designs that were considered and that were supported. But only the AP 1000 design type ever made it into an actual license. Another program in the Energy Policy Act of 2005 was the NGNP program, which was designed to deploy a high temperature gas reactor, an advanced technology which was effectively a high temperature gas reactor with significant federal support, there was federal requirements for the Department of Energy to support this program.

Over a billion dollars or more was actually spent on the program. And it was cancelled in 2015, with no reactors built. So again, this is you know, these all look very similar to the kinds of things that are happening today. And the outcome ultimately was no reactors built. The SMR licensing also, again, was started a little bit later in this kind of way, but again, started over 10 years ago. The idea was to support two small modular reactor designs going through the licensing process to demonstrate that they could do that. Two awards were issued one was to empower a BWXT, a joint venture with Bechtel. That program was terminated in 2017 and they never built any reactors. NuScale did continue.

They went through this entire SMR licensing support program. However, they did not deploy any reactors and have yet to deploy reactors. And again, it's important to recognize what the goals of these programs were, this was intended for SMRs that could be deployed expeditiously, and in that timeframe, expeditiously meant by 2022. And here we are in 2023, and no SMRs that were supported in that program have actually been deployed. So, you know, I want to say that, you know, I won't go through the slides in detail, but a tremendous amount of work has been done, certainly on the licensing and regulatory side to prepare for building reactors.

Many early site permits were issued, which is a way to expedite the licensing process or segregate the licensing process so things could be done in advance to ultimately make it faster. A number of early cite permits were issued, and the ones underlined happened to be the ones that were supported under New Start the NP 2010 program, the one in bold is Vogtle in which they actually have built in a plant that one of the reactors there is operating at full power, and others that were withdrawn or never completed. If you look at design approvals, which is another element of this process, the Nuclear Regulatory Commission has approved many designs for reactors.

Of those, only the AP1000 has actually been in construction. A number of designs were proposed and then never completed. And all of this is, you know, of some of those design certifications, with the exception of the last three on those issue design certifications, those have been saying a prior wave of this issue of this of this period. But the last three were all in this timeframe of between 2005 and 2012, or 13, let's say. So during this kind of first wave of efforts to stimulate reactor development, as I said, almost no reactors have come out of that.

Many, many licenses have also been issued, as you can see here, at least seven to eight licenses have been issued for new reactors in this country, and only two of those have actually been built close to completion. Vogtle unit three did complete recently. And Unit Four is on track, I guess, sometime early this year or late next year, to complete. But as you can see, a tremendous amount of effort went in to proposing these reactors and nothing really came out of it. Which, I think is an important lesson as we think about how we're going to use and try and use nuclear reactors as a climate mitigation strategy.

There was a huge effort to try and do this 10-15 years ago, and it led to almost nothing. So again, this is just a list of the COLs (the licenses) for reactors that have actually been issued. As you can see, a number of those have been terminated. BC summer units two and three were actually terminated after significant construction. The others were terminated before any real construction was done. But there are actual licensed plants that in principle, one could build today, if there were the interest and appetite, and there simply isn't to do it for cost reasons, and other reasons. So that's just to sum up where that kind of first wave wound up looks. And I've gone way over my time here.

The large reactor stimulus, which was intended when I was chairman of the NRC, there, we had 18 applications for 28 reactors. It was the culmination of this nuclear power 2010 program, the culmination of the Energy Policy Act incentives that were intended to drive this nuclear renaissance. And what came out of it was one reactor as of today, that's in operation six to seven years late, and a second reactor that will come online again, six to seven years late.

The cost estimates are more than doubled, certainly what the initial estimates are (or were), and more importantly, they have priced these reactors out of really being a viable generating source for any reason, whether it's to solve climate or any other any other energy/electricity need you might have. You can look then to the SMR is which were also started kind of in the middle of that first wave and look to NuScale.

The problem with NuScale is they still don't have a finalized design. It's now 2023. They had a design, certified that design, while it had its certified with an asterisk, meaning that the design was approved by the Nuclear Regulatory Commission, but with a number of issues that would have to be resolved when they actually get to the licensing of the facility. It's a kind of a design approval with an asterisk. However, that design isn't even the design that NuScale is currently planning to deploy at a reactor site in Idaho.

That reactor design is going back to review at the NRC and as of now, they haven't even submitted the design that can actually be, you know, in the technical jargon, ‘docketed’, which means at the NRC can accept it and begin reviewing it in a formal way. This is kind of their second or third bite at the apple on a design. And they can't get that design doc as of March of this year when that design was supposed to be submitted in December of last year, and then docketing is usually a process could take a month or two.

Then the NRC says ‘Yes, it meets all our minimum requirements, we can now work on it’, they can't dock at the current application. So that doesn't bode well for reactor being built in the next five to 10 years. I give you all that historical context to look at what we're seeing now we've got significant new stimulus for new advanced reactors. This is kind of a new wave of effort to try and build support for nuclear reactors. We have probably the most actionable is the advanced reactor demonstration program, which was started in 2020, which has upwards of billions of dollars in stimulus. Again, you have to look at the metrics and the guidelines for these programs.

The first phase and the most actionable phase, which I'll focus on the most, was to award grants for two reactors that could deploy rapidly, meaning that could deploy and be operational in five to seven years. So 2025 to 2027, that's two to four years from now. And I'll just skip to where they are. Both of those reactors are in what's called pre application with review for the NRC, which means that they don't have an application yet that the NRC can actually review. Based on historical trends it’s almost impossible for those reactors to be built in the next four years. They still have to actually finalize an application, submit that for review, actually get a license application then, and then actually build the plants. It's unlikely that these plants will be online in 2025, or 2027. Perhaps they'll be online by 2030. Coming back to what does all of this mean. Well, our goal is if nuclear is going to play a significant meaningful contribution in climate change, plants need to be able to deploy at scale in 2030, in order to contribute meaningfully by 2035. And right now, we're looking at best to see demonstration reactors that could be built by 2030. And certainly, it's unlikely that even if the demonstration reactor were to come online in 2030, that you'd then be able to turn around and deploy at scale, because there aren't really any other sites that are actively looking for reactors right now. There are very few sites that have applications in progress.

So maybe you can have a handful of nuclear reactors in the next 10 years or so. That's not going to contribute meaningfully to climate change mitigation and abatement. And, you know, that's just the status of the industry. People may like it or not like it, but that's simply the way it is. And when I wrote an op ed in 2019, the situation was largely similar. That's where I came to the conclusion that nuclear was not going to be a meaningful contributor to climate abatement. It was simply going to be a distraction, and I think I'll turn it over to Mark now who I think will cover that and cover what the alternatives are.

Cindy Folkers: Moderator

I will now be pleased to introduce our second speaker, Mark Z. Jacobson, who is a Professor of Civil and Environmental Engineering at Stanford University, where he directs Stanford's Atmosphere Energy Program, and is a Senior Fellow of the Woods Institute for the Environment and the Precourt Institute for Energy. He co-founded the solutions project, one hundred.org, and the 100%, clean, renewable energy movement. And he is the author of several books, including his latest, *No Miracles Needed: How Today's Technology Can Save Our Climate and Clean Our Air.* Dr. Jacobson, welcome.

Mark Z. Jacobson: Panelist

Thank you for the kind introduction. I'm just going to talk briefly about issues with nuclear but I want to put it in context. You know, the problems I'm looking at trying to solve our air pollution and global warming and energy security, simultaneously.

7 million people die from air pollution each year, worldwide, hundreds of millions more are ill. This is a problem that if we stop emissions, the faster we stop emissions, the faster we save these people's lives. On the order of $30 trillion per year, based on statistical cost of life, global warming is expected to cost 25 to $30 trillion per year by 2050. And also, energy security is a significant problem. With regard to global warming in order to avoid a 1.5 degrees global warming we would need to eliminate about 80% of emissions from energy and non-energy sources by 2030 and 100% by 2035 to 2050. This means we really need 80% transition by 2030. And if we have a technology that we can't even implement in 10 to 15 years, that means that technology is not going to help at all to try to solve the global warming problem, let alone to solve the air pollution problem that we need to solve this year and next year. These are problems that require drastic solutions. So what are the issues with nuclear?

Well, to start with, it's not carbon-free. If you actually account for all the relevant emission sources, associated with not only the opportunity costs, but also the building and running of the reactor, it's nine to 37 times the co2 equivalent emissions and pollution per kilowatt hour of electricity generated and wind. And I'll show you the details in a second.

It takes 10 to 22 years between planning and operation of every single nuclear reactor ever built. And most recently, it's mostly between 17 and 22 years in liberalized markets, and versus 0.5 years for rooftop solar to three years of well, it's between 0 to 1 and three years for utility scale, wind and solar. So there's already you can see the fact that we're going to, if we're going to invest in one technology, such as nuclear versus wind and solar, we're pretty much committing ourselves to not solving the climate problem on any short timescale. In terms of capital cost is 15 to 24, times the capital cost for new nuclear compared with new wind or onshore wind or utility scale solar.

That's the capital cost, and the annual-- the levelized cost of energy is about five to 10 times higher of new wind or solar. Nuclear never put in—because of the time lag between planning and operation, nuclear will never pay off its CO2 and pollution emission that causes. You know, 10 to 22 years, while you're waiting around for a nuclear plant being built, you're emitting from the background electric grid, versus one to three years for wind or solar. You're basically spending an extra, you know, on the order of 15 years of background grid emissions, and that will never be paid back during the operation of a nuclear plant, particularly when you count for the cost that you could have invested that same money in a lot more wind and solar. It's not helping and it's an opportunity cost in terms of carbon dioxide and in terms of actual energy generation.

In addition, the Intergovernmental Panel on Climate Change even agrees there's robust evidence and high agreement that increased use of nuclear power leads to more weapons proliferation risks, meltdown risk, waste risk, and mining risk. Several of these are energy security problems. In terms of solving the problem of climate change, and air pollution, and energy, security, nuclear is no help whatsoever. Let's look at some more details here. The time lag between planning and operation. This is not just the construction time, it's the site permit time, which in the US takes 3.5 to six years, construction permit approval and issue time, which is 2.5 to four years. And then construction time is four to 17 years. It's 10 to 22 years between planning and operation. Compare with coal was about six to 11 years, biomass four to nine years, hydroelectric power eight to 16 years. Geothermal is three to six years. Wind is one to three years now, CSP is about one to five years. Utility PV is about one to three years, and rooftop PV is about 0.5 to two years. The time difference between the planning and operation time of nuclear versus any of the other technologies is what we call the opportunity cost. And there's emissions associated with those opportunity costs.

Just to give you ideas of actual nuclear reactors, Olkiluoto in Finland, which just came online within the last couple of months, there was a construction time of 17 years of planning to operation time of 22 years. Hinkley Point in the UK, it's expected to come online somewhere in 2026, but that will give it an 18 to 19 years of planning to operation time. Vogtle three and four as Greg just mentioned, one of them just came online. So that's 17 to 18 years between planning and operation. From when it was first planned, Flamanville in France 20 years. Even in China, there have been Haiyan one and two in 13 to 14 years Taishan one and two in 12 and 13 years, and going back a long time, there are four nuclear plants in Sweden built that were 10 to 18 years. Even the French nuclear whole Mesmer plant—each of those individual reactors took 10 to 19 years between plan, planning and operation. What about the CO2 emissions associated with nuclear? Well, most people are really familiar with the lifecycle emissions.

If the estimate from the IPCC, or the range from the IPCC is around five to 110, our estimate is nine to 70 grams of CO2 per kilowatt hour. That's for the construction of the nuclear plant, and its operation and decommissioning at the end of its life. But pretty much everybody ignores this opportunity cost, which is the emissions associated with the time lag between planning and operation of the nuclear plant versus that of another technology in this case, which has zero opportunity costs, because that's what it's compared with 64 to 102 grams of co2 per kilowatt hour.

What about the heat from the nuclear reactor?

Nobody accounts for that the actual heat is about 1.6 grams of CO2 equivalent per kilowatt hour of electricity. What about the water vapor from the nuclear reactor due to cooling water you need and the resulting evaporation? That's 2.8 grams of co2 per kilowatt hour, while weapons proliferation risk, people will debate that, but it's pretty small. Then just covering land with the material with the with concrete on the ground is a pretty small number too, but it's 78 to 178. But 78 is the total, mostly opportunity cost and life cycle emissions, but also water and heat.

Compared with offshore wind, the lifecycle is seven to 10.8. There's no opportunity cost by definition. Heat, onshore wind farms, wind turbines actually decrease global temperatures, they'll increase temperatures right downwind of the farm, because in the mechanism of reducing heat, by wind turbines as they slow down the wind that reduces evaporation, and evaporation as a cooling process. Less evaporation means that you warm the ground downwind of the wind farm. However, because you have less water vapor in the air, there's less condensation of that water vapor to form clouds in the air. So that in condensation, releases heat, so you have less condensation, so that cools the air. So those two processes cancel out. But now you have less water vapor in the air, and water vapor is a greenhouse gas. When you actually account for the greenhouse gas cooling of lots of wind turbines, you get a net cooling of climate due to wind turbines. And that's about minus 1.7 to minus 0.7 grams of co2 per kilowatt hour. You also have less water vapor, as I mentioned, and the combination of those two effects cause wind turbines to actually reduce global warming on their own, in addition to offsetting co2 emissions. And so when you add that up, it's 4.8 to 8.6 grams per kilo grams of co2 equivalent per kilowatt hour. It's nine to 37 times the emissions for nuclear compared with onshore wind. It's not zero emissions for nuclear.

What about let's do an example of actual cost and lag times with Vogtle, so Vogtle was 2.23 gigawatts for two reactors. It's cost $35 billion dollars so far, and took 17 to 18 years between planning and operation. In the first quarter alone worldwide of 2023, there were 23.5 gigawatts of wind installed at a capital cost of $15.2 billion, which is point six $5 a watt. Versus 15.6 billion—sorry, $0.65 watt versus, versus $15.6 a watt for the Vogtle plant.

These wind farms took one to three years from planning to operation. If we just took $35 billion for Vogtle, that could either buy this 2.23 gigawatts of nuclear, or it could buy 54 gigawatts of wind worldwide. In other words, for the same amount of money wind provides almost 25 times the peak output, and 10 times the annual average output as nuclear for the same money and 14 to 17 years faster, with nine to 37 times less co2 equivalent emissions per kilowatt hour. Which would you rather spend money on: something that can get 10 times more energy output, on the order of 15 years faster, or something that's going to be much more expensive and slower?

The alternative, and I'll just really brief and wind this up now, the alternative to using nuclear is just going to clean renewable energy. Transitioning all energy sectors, that's electricity, transportation, heating, cooling and industry to existing technologies. We have 95% of the energy technologies we need to transition.

We have storage technologies—we need electricity storage, heat storage, cold storage, and hydrogen storage. And so we have the existing technologies in terms of the generation. We have most of the storage we need. Batteries will probably dominate in terms of storage in the future, and the cost of batteries has come down significantly. We've developed plans for 145 countries worldwide to transition to 100% renewable energy. We find that the end users demand in 2018 of all these countries were 13.1 terawatts. If we go to 2050, that'll jump to 20.4 terawatts of unused demand, electrifying all energy providing with just wind and water and solar, which you can implement quickly, as we've discussed, you go down about 56% due to the efficiency of electric vehicles, the efficiency of heat pumps, the efficiency of electrified industry, eliminating mining for fuels, and energy use/energy efficiency improvements.

We get a 56% reduction of power demand without changing our habits by electrifying and going to clean renewable energy. We could then provide the same thing, but a timeline from 2020 to 2050. Showing that if we don't do anything, we go along the top line. If we electrify and provide electricity (clean renewable energy), we go down those five shades of colors to 100%, wind, water, and solar line with 8.9 terawatts of demand. This shows an 80% transition by 2030s, which we need. If we go down the nuclear path, we can't have anything close to this transition, because you just can't put up nuclear in anytime soon. Even the small modular reactors, as Greg said, you won't even have test reactors available till 2030. We need 80% transition by then. And this shows 100% by 2050.

The capital cost of transitioning based on projected costs of clean, renewable energy and storage for everything is about $62 trillion worldwide. In the US about 9 trillion and China about 13 trillion. But what's really important is that the annual cost of energy, business as usual, in 2050, that's $18 trillion per year we're spending on energy, but on other health and climate cost of $60 trillion dollars for $83 trillion per year social costs. If we electrify going clean, renewable energy, we reduce power demands 56%-- cost per unit energy another 15%. The social-- the energy cost is now $6.6 trillion per year with wind, water, solar down 63%. We eliminate health and climate costs, and so we're down at social cost of 92%. So just to summarize, you know, if we can transition to just 100% clean renewable energy we will create millions more jobs--20 million more jobs than lost-- worldwide long term full time jobs; we'd require less land than we currently need currently need for the fossil fuel industry; we'd avoid 7 million air pollution deaths, slow then reverse global warming; we can keep the grid stable with 100% clean renewable energy at an energy cost of 63% lower than fossil fuel costs, and the social cost 92% lower. I'll stop there. Thank you very much. And just here are some references.

Cindy Folkers: Moderator
Thank you very much Mark. As a reminder, we will be answering questions at the end of all presentations. And so now I am pleased to introduce our third speaker, M.V. Ramana, who is a professor and Simon's chair in disarmament, global and human security at the University of British Columbia School of Public Policy and global affairs, where he also directs the Master of Public Policy and global affairs program. Ramona has published several peer reviewed papers and reports on small modular nuclear reactors, known to us mostly as SMR's. Dr. Ramana, thank you very much. And welcome.

Dr. M.V. Ramana: Panelist
Thank you, Cindy. Thank you to the organizers. And thank you all for inviting me. It's an honor to join Mark and Greg, on this panel. They both covered a lot of ground. So my job is fairly easy. And I'll be quick. I'll just sort of reinforce some of these points and add a few of my own. I'll start a little bit with a picture that Greg sort of showed briefly, just to mention a couple of points.

The first is that the best days of nuclear construction, were over nearly three decades ago. You can see in this graph, the rate at which reactors were started up. And you can also see that since the mid-1980s, there have been nearly as many reactors that have been shut down, as have been started ups with the result that the global nuclear capacity is more or less a constant. It goes up a little bit comes down a little bit. This partly means that when you look at the share of electricity that nuclear power plants around the world contribute to the grids, that share has been declining almost continuously since the mid-1990s. The maximum it ever was about 17.5%. In 2021, the last year for which we have detailed data, it was 9.8%. By all accounts, it's probably going to come down to a little over 9% for 2022. That seems to be where we are headed at. During the same period, you can see there's been a dramatic increase in the share of renewables. Renewables, like the ones that Mark talked about wind and solar, and not including large hydro dams. That's now around 12 or over 12%, at this point, and this increase is for the reasons that, again, Mark sort of mentioned about how fast it can be built and how cheap these are.

If you look at the prognosis, this trend is very, very likely to continue, that renewables will be growing and share and nuclear is going to be declining in share. So as far as if you were to think about nuclear power as a solution to climate change, then the first prerequisite which is that nuclear power ought to be increasing its share is just not borne out in the data. And why is this the case exactly again, a reason that has been mentioned already, nuclear power is just not economically competitive, in large part because nuclear reactors cost too much to build. And that cost has actually been going up over the years. If you look at this graph, which is a plot of the levelized cost of energy, that's the cost per megawatt hour, from different sources that was produced by this Wall Street company called Lazard, what you'll see is that solar has declined by about 90%. In about the last dozen years or so, whereas nuclear power has increased by about 36% per megawatt hour, this is sort of reflecting the huge cost increases that Mark talked about.

This is not just a recent phenomenon, one study that looked at over 180 different projects, funded 175 of them had exceeded their budget, and was by an average of about 117% in increase, which means about $1.3 billion per project. But of course, these recent projects have been much more expensive. And then those cost increases, as you know, has meant more in absolute terms as well. They also almost always are delayed.

Again, I'm sort of repeating what Greg sort of talked about, which is that there was supposedly a nuclear renaissance happening in the United States. And on 30 reactors were ordered, and 15 of them were supposed to be starting operations by 2021 only four of those actual reactors began construction, and two of them in the state of South Carolina were abandoned after over $9 billion were spent. What we are left with is the mobile plant which Greg has talked about.

The one other thing I should sort of mention to this is that the traditional argument in the nuclear industry has been that we know that the cost of building nuclear reactors is high, but they cost a relatively low amount to operate, because sa little bit of uranium goes a long way. And so, the idea was that in the long run, reactors would make money. And that story has come undone in the last decade or so. And what we saw are several reactors shutting down because of high operational costs and availability of cheaper alternatives, with the result that around six or seven years ago, nearly a third of the fleet was supposedly in trouble.

To give one concrete example, the Duane Arnold plant in Iowa was shut down in 2018 and 2020. The announcement from the utility basically said that by shutting this down, we will be saving customers around $300 million, because we will be replacing the energy from Duane Arnold with wind energy.

In the light of this scenario, there's been a lot of talk about small modular reactors and I thought I will focus my presentation a little bit on those for a few minutes. There's if you read the media, you will see that there's a lot of very positive coverage of small modular reactors, and they are described as being safe they are described as being cheap. They are described as producing less waste or even reducing overall waste by burning it and so on and so forth. But the reality is that all of these desirable goals will simply not be realizable in a single design. And the reason is that in order to do any of these, for example, if you want it to burn some of the waste by fissioning some of the transfer annex in the reactor, then you will need a fast reactor and a fast reactor means that there are special safety challenges, which make them somewhat more vulnerable to certain kinds of accidents. And small and fast reactors also have historically been more expensive to construct. But the more important problem is that the main challenge for nuclear power, as we mentioned earlier is the high costs of nuclear reactors.

Small modular reactors will not fix that problem because when you go smaller, you lose out on what are called economies of scale. A reactor that generates five times as much power does not require five times as much concrete or need five times as many workers, but it will produce five times as much electricity and revenue. And therefore, this is the reason why the nuclear industry, which initially started by building smaller reactors started building began to build larger and larger reactors. And that when you sort of go back in history and try to go back to smaller reactors, you are going to make your sources of power more uneconomical. Smaller also means that all else being equal, it will probably produce more spent fuel and waste, simply because these reactors are going to be less efficient at fissioning the uranium because more neutrons will escape from the surface.

The nuclear industries answer to this is that, oh, we know that we're going to lose out on economies of scale, but because we are going to be making these in factories, we can manufacture large numbers of them, and by that means we can reduce it.

There are two things to remember. One is that the idea of modular construction in factories was what was supposedly going to make the AP 1000s that were built in Vogtle and in China cheaper, and that just didn't happen. We saw the same kind of patterns of delays and cost increases. But also, if you look historically at a fleet wide level costs of reactors have increased over time rather than decreased. This is true both in France and the United States, which have the two largest nuclear fleets anywhere in the world. And the other thing is that even if we were going to have some kind of learning and reductions in costs, sort of going against historical trends, you would have to build far too many of these small modular reactors, before they even break even with large reactors.

As all of us have emphasized in this presentations, nuclear powers, even with large reactors is simply not cost competitive. Small modular reactors have absolutely no chance of being cost competitive in today's market.

The other thing with certain kinds of small modular reactor designs, especially the non-Light Water Reactor ones, is that they produce wastes in forms that are difficult to deal with. You know, these are chemicals that are not known to occur in nature, things like sodium bonded fuel might result in, you know, the metallic sodium that has to be removed from it, and therefore, some kind of reprocessing might have to be done, and these are all difficult challenges and only make the problem of nuclear waste management, which is already extremely hard, even harder. I'll also say that because these are nuclear reactors, there is absolutely no guarantee that they cannot have accidents. Even a small reactor can have accidents, because we simply do not know all the possible ways by which the reactor can proceed to an accident, and therefore, we can't protect through all of these things. So the idea that there's something called safe nuclear power, which means that there is no accident is just not a feasible option. And lastly, at a global level, if you think about nuclear power as contributing to dealing with climate change, then nuclear power will have to expand in a very large number of countries which are all growing rapidly and demanding more and more energy. These are countries like India and Indonesia and Nigeria and so on and so forth.

And the question to ask is, if all of these countries were to acquire nuclear power plants, they also get the capacity to make nuclear weapons because even a small reactor rig has fairly large requirements for either uranium enrichment or will produce relatively large quantities of plutonium.

Therefore, there is going to be fairly large capacity to make nuclear weapons, whether they choose to make it or not, is a matter of choice rather than of capacity. And this is something which we want to think about when you consider the all the debate over what Iran is doing. For example, would you want to have similar debates about other countries? So just to sort of summarize, you know, this is true for both the United States and elsewhere, should we expand nuclear power to solve climate change? You know, there are sort of three sets of properties which make it uniquely undesirable, the risk of accidents, the fact that it is linked with nuclear weapons proliferation, and the production of radioactive waste that are very hard to deal with.

Because of the timelines of how long it takes to build reactors and how costly it is, it's not a feasible solution to climate change, either. I will stop here. There are lots of questions. I look forward to answering some of them. Thank you very much.

Cindy Folkers: Moderator

Thank you, Ramana, thank you very much. We will now go to questions. As a reminder, please put your questions in the Q&A box rather than the chat. We already have a number of questions that are there, we're trying to combine them for topic and subject matter so that we can have a good discussion and try and cover a lot of the questions. We will also provide contact information to follow up on questions after this briefing has concluded. What I suggest we do is I'm going to ask the first question, and it's going to be on baseload power. ***What would be your suggestion***, and this is to all three panelists, so please feel free to answer, ***for how power grids balanced the intermittency of wind and solar and baseload low carbon generation if not nuclear, given the battery storage right now can deliver about four hours of output to the grid?***

Mark Z. Jacobson: Panelist

Well, I'll try to answer. First, nuclear does not—I mean, demand for energy is variable. And is continuously variable, and nuclear provides a flat supply, and then it's down, you know, on average, 10% of the year in a lot of places. But in France, for example, it was down 48% of all 2022. And so nuclear does not match demand. You do need backup, you need hydropower, or natural gas or batteries to provide the difference between the base layer that's provided by nuclear and the actual demand. It's a prevailing myth that just renewables will require backup but nuclear does not. Renewables will probably require more backup, but nuclear does require backup. So we've done simulations worldwide, that combining wind and solar for example, you reduce the intermittency of the two, combining wind from geographically dispersed locations on the transmission grid, you reduce the intermittency, so you get, you can make wind, about 30 to 47 times percent of the reliability of a coal plant, just by interconnecting it over a geographic region of 850 kilometers. Then you use solar as well, because wind and solar are complementary in nature, use hydroelectric to fill in the gaps use more batteries for backup. Beyond that batteries have come down to $150 a kilowatt hour and they're expected to be less than $100 a kilowatt hour by 2026. Once they get to $60 a kilowatt hour, the game is over. And we can power everything, just wind and water and solar and battery storage at low cost worldwide.

Dr. M.V. Ramana: Panelist

Great answers from Mark. I just had one thing that there's also the possibility of demand side responses, which can probably lower the requirements for storage. And you know, recently, there's been a lot of talk about so called virtual power plants. And of course, in California where Mark is, you know, the utility has been using that.

Mark Z. Jacobson: Panelist

But I'll just add one more thing. California's grid right now has 3.3 gigawatts of batteries on it. And the average demand except for summer is about 27 gigawatts or, you know, we're 1/9 of the peak demand, except for summer is already met, met by batteries, and there's going to be another four gigawatts added the next week before September. So batteries are being implemented not only in California, but worldwide really rapidly.

Cindy Folkers: Moderator

Greg, do you want to add something?

Dr. Gregory Jaczko: Panelist

Yeah, I'll just add, I think this issue of baseload. It's also very challenging issue actually for the nuclear power industry right now, because one of the challenges for grid operators right now is time, generation of wind and solar. So, you know, we tend to not necessarily look at these issues on almost an hourly basis when it becomes important from a nuclear power perspective, because plants in the US are not designed to do what they call load follow, which means that they can modify power output based on basically fluctuating needs in the power grid. And everyone's maybe what many people are already familiar with the famous duck curve from California, which shows that as power solar from distributed and utility scale kicks on in the middle of the day, the demand for other resources drops almost to zero and it's close to zero, I think it's probably hit zero recently. But that's a very challenging operational environment for nuclear reactors for two reasons. One, because in the US plants are not licensed and designed to shut down in the middle of the day, and then ramp back up in the later time or but also, because financially, they're built around the idea of operating for that 90% of their capacity, because that's how they're able to manage the high operational costs that come with nuclear reactors.

This is a challenge, not just really for new reactors, but this is a challenge for existing reactors to stay competitive on the grid. You know, people are talking about potentially moving some of that power midday into battery storage from reactors. When you've started to say that you've got a fundamental problem with this asset, because, the idea of baseload power really isn't a valid concept anymore. We don't operate on a grid now, where power is produced on demand by grid operators, it's now produced largely by nature, and then the grid, the grid adapts around that. And nuclear is not well suited to that. And that is a challenge that you'll see going forward.

Cindy Folkers: Moderator

Great, thank you.

I would actually like to say that, although we had this briefing scheduled for an hour or so it would be ending at 2:30. We are open until 3:00 for questions. We will continue to answer the questions that have come in. The next question, let me see. ***How will wind and solar scale? Will they be able to accommodate people who are in lower population areas?***

Mark Z. Jacobson: Panelist

Well, every location worldwide will have a different set of clean, renewable energy resources. I mean, some places already have a lot of hydropower, for example, there are nine countries in the world that are 100%, just wind, water and solar.

They're all dominated by hydro. There are several that are close that are actually dominated by wind. And I mean, Scotland's, like 91% of its consumption is powered by almost all wind. And in fact, in the US, South Dakota, is the state in the US with the highest fraction of their electricity generation from just renewables. It's 84% with about 54%, wind and 30%, hydro, and also other states and in the US are over 60% renewables, and most of them are pretty remote.

To get remote you'll have a combination of wind and solar, some places hydro, and storage. But yeah, we do need more transmission in several places. So that will be the key, I think that is one of the stumbling blocks is how do we have more transmission. That's more of a zoning issue than anything else, it's not so much a cost issue. But trying to get permissions to zone. and that's also a problem a lot of the US has. A lot of other countries don't have that issue.

Dr. Gregory Jaczko: Panelist

And I think that to add to that too, unless you're using a bulk transmission system where you are building transmission lines to access rural areas, there's certainly not a viable nuclear solution for that. Again, in the mid-2000s, there were a number of proposals for very small reactors, on the range of 10s or 20 megawatts, again, we had a design from Toshiba that was talked about quite a bit as a solution for Alaska to replace diesel generators that may have powered remote communities.

That's simply not a viable option for technical reasons for proliferation reasons and cost reasons. So there certainly are, from a distributed perspective, way to utilize distributed resources like solar with local storage, to even power some of these rural areas without connection to the bulk power system, which in many ways can be more resilient system than the current system that we've built up around large generators, and then transmission filling in, in connecting communities. Now we have the ability to bring generation directly to communities with distributing solar and battery solutions.

Cindy Folkers: Moderator

Okay, so thank you for your answers on that. I have another question. ***Would a firm timetable for phasing out the existing reactor fleet incentivize investments in renewables? Would the replacement power for the phased-out reactors have to be fossil?***

Dr. Gregory Jaczko: Panelist

It’s interesting. I think the phase out will largely happen on a natural low as the essentially market factors in economic competitiveness, drive reactors out. And the simple answer is no, I mean, that won't have to be replaced by fossil. I think there's a myth around that. There's some, I think, very misleading information that's come out of the Department of Energy that, you know, if you look over the last 10 years, a number of reactors have shut down. And in for some of those reactors that have shut down, some planned, some unplanned. In some but for not all, you see a short blip in in carbon emissions in that state, let's say over that year or so. But within two to three years, you're typically back down to a trendline of decreasing emissions. Because of deployment of wind. In that time period, primarily, we're talking about over the last decade or so, a significant amount of wind has come online. And or solar other carbon free or a fuel switch from natural gas to coal.

There's really no strong correlation between reactor shutdown and carbon emission increases from a purely, I think, technical perspective on the grid. Any issues like that are really more driven by policy. And I think right now, we're in an era where policy is working against the renewables in a way that I think we haven't seen in a long time. Because, I think to say, because they're winning, and that's putting pressure, certainly on the nuclear industry, which I think manifests in the massive amount of media coverage about nuclear climate solution. And you're starting to see it now, I think, in efforts to preserve fossil resources. And to really limit the ability of solar and wind expansion for NIMBY reasons or other issues that I think are driven largely by political objectives to maintain fossils. So, there's certainly no basis for thinking that nuclear would be replaced by fossil.

Mark Z. Jacobson: Panelist

I think that any nuclear plant that requires subsidy should be shut down; because first of all, that plant is going to need to be replaced shortly in any case, and that subsidy could have been used not only to—so there's a certain amount of money that would have been spent anyway to replace that nuclear plant. And then plus, on top of that, there's that subsidy that could be used to produce even more wind and solar. And so for example, in New York, they subsidize three reactors to the tune of over $7 billion for 12 years, and so they're going to shut down in any case in 2028. But that $7 billion, it would cost about $9 billion to replace the nuclear plants with wind and solar. In addition to the fact that we have to spend 9 billion, they'd lost 7 million. So that's 16 billion that could have spent on replacing more wind and solar. So that would have resulted that would have resulted in more carbon savings. If they'd actually invested that money in replacing the nuclear plants.

Diablo Canyon is being kept open, and the initial subsidies $1.4 billion, and it's going to be more costly to keep that plant open. But on top of that, Diablo Canyon is basically hogging the transmission line to the coast. And there's a lot of offshore wind being planned right offshore of where Diablo Canyon is. But because there’s 2.2 gigawatts of nuclear being on that transmission line, that means there's that much less wind can be added (offshore wind). It's not only hogging a subsidy and causing costs to go up as a result of the subsidy, but is preventing new renewables from going in California and hogging the transmission line. This is just an example of bad policy that delays a real solution to the problems of climate change and air pollution.

Dr. M.V. Ramana: Panelist

Yes, I’ll just add one point, which is to say that it's not just true in the United States, it's true elsewhere as well. And the case of Germany I think, is illustrative because Germany decided to phase out nuclear power and it started really investing in renewables at a time when renewables were far more expensive at that point. And so there's also a political determination that goes with the idea of phasing out nuclear power to replace it with renewables. And what Germany has shown is that all of the electricity that the nuclear power plants used to generate have more than been made up by renewables at this point.

Cindy Folkers: Moderator

Great, thank you, the next question the industry continues to ask actually, two questions. One, each coming from opposite sides of the argument.

The industry continues to ask for shorter reviews. And the NRC has already shortened to them as part of NEIMA. What would further reductions to reviews mean? And then the other part the opposite sort of piece to this issue is, Is the problem nuclear power? Or is it the US regulatory approach? Other countries have built reactors.

Dr. Gregory Jaczko: Panelist

Well, I guess I can take that one. You know, when I started as chairman of the Nuclear Regulatory Commission, I asked the Bipartisan Policy Commission committee to take a look at the NRC's new reactor licensing process. And this was a study that was held led by Dick Meserve, who was a former NRC Chairman, very well connected in the industry. And Pete Domenici, who was the chairman, who was retired but had been very prominent nuclear energy supporter. The result of that report came back and said, yeah, there's nothing wrong with the licensing process. I mean, the NRC is able to license reactors efficiently and effectively when advocates come in with well-designed and proper licenses and license application. The problem we see is that there's a tremendous, I think, desire to want to blame the NRC for the problems of the industry, take NuScale, as an example. NuScale came in, they had an application for what's called the design certification, which is basically an approval of the design.

They ran into technical problems, the NRC identify technical deficiencies in their reactor, which they were not able to address. The NRC still gave them a design approval. And like I said, did it with an asterisk that indicated they, they had issues, they still had to figure out. Maybe these weren't issues that were, from an agency that was, you know, trying to hold up licensing, they were doing everything they could to get the plant licensed, but the application had deficiencies. Fast forward now, they got that design approval, they still want to build a plant in Idaho. They came forward with another design.

They expanded the module sizing on these SMRs. I mean if you want to look and say that that's taken a long time to license that plant, that's not the fault of the NRC. The industry can't settle on a design. The NRC went through the licensing of Vogtle three and four. That was about three to four years, which was the metric that we had established. It took Vogtle over 10 years to build the plant when they said they would build it in five years. That's not a regulatory problem. And there are almost no plants in what we would call a modern nuclear regulatory country that have been able to license reactors and build them any faster than the United States.

Ramana and Mark both touched on Olkiluoto. They touched on Flamanville, which is a plant in France, which I think is still not anywhere close to being finished. These were all plants that were supposed to be online and operating when I was still chairman of the Nuclear Regulatory Commission.

There clearly is an underlying problem here that isn't about the regulatory process, because the regulatory process has been modified and to that, you know, as much as possible to make it as lean and effective. But you cannot, you cannot substitute for poor quality in the applications. And that's fundamentally what we're seeing these simple designs are simply not bait. I mean, I'll give you one more anecdote. So this again, this was when I was a chairman of the NRC. SMRs were becoming very popular. I mean every reactor designer out there had an SMR because Congress was talking about it and they were talking about money, and they were talking about offering subsidies for SMR deployment.

Holtec designed a reactor. Westinghouse designed a reactor. BWXT had a reactor. NuScale had a reactor. These are all SMR designs. These are not complicated reactor designs by any stretch of the imagination. They're light water reactors that are smaller with fewer components. So we tried to narrow down the number which led to that SMR support program that I talked about, because half of the people that were coming talk to us didn't have a fully baked design. But they were after the subsidies, they were after the information or the money.

And they knew here was a chance to throw something together and say they had a SMR design and then try and get it licensed by the NRC. And I said politely, that's not our job. Let's limit it to two. Because that way, we'll force it to actually be two credible applicants, and you can award those two, and then we'll plan to license those two to the DOE. That's what I said to the DOE. You know, again, I can go on for hours and hours and hours, but the regulations are not the problem, they have never been the problem. You know, it is fundamentally a complex technology that the industry is challenged to properly design and engineer, because it's complex and difficult. I think the data points, demonstrate that extensively.

Dr. M.V. Ramana: Panelist

Yeah, just very briefly. Greg already mentioned how various other countries are also not succeeding in this, whether it's the UK or France or Finland. The only—and I sort of, I can also talk a lot about India, where I have been following. In India, too, you know, they've been wanting to build nuclear reactors for a very long time. But it's been at around 3% of the country's electricity comes from nuclear power plants. And it stays that way, the only place that builds reactors with any sizable numbers is China. But China builds everything, right, they're building, they're expected to build about 160 gigawatts of solar and wind in just this one year. So you know, China is sort of something else is happening there. We can't sort of get into that right here. But clearly what China is doing, no other country in the world can do.

Cindy Folkers: Moderator

Okay, thank you very much. I just want to do a time check. We've got about 20 minutes remaining. And we have four questions left that I think I'd really like to get to. So let's just watch our time. And we will start with the question. ***Is the nuclear industry dealing with the reality that they want to produce more nuclear waste without dealing with the current nuclear waste crisis?***

Dr. Gregory Jaczko: Panelist

I think everyone's dealing with that. I don't think it's just the nuclear industry. I mean, everyone involved in anything related to nuclear is not dealing with the nuclear waste problem. While you know, anyone who's supporting and promoting nuclear power, whether it's Congress, or the administration is not fully dealing with the nuclear waste problem. You know, one could argue I think whether that is, compared to the calamities of climate change, I don't think that nuclear waste is the most pressing issue, if nuclear did not have all these other problems that we've talked about. But nonetheless, nobody's dealing with that. I think the NRC punted on this issue, very famously within the regulatory world with something called waste competence, which is essentially the NRC saying we're not going to address the issue of waste when we license reactors.

I was involved with that as well. It basically made a blanket statement that essentially says, we don't worry about waste, eventually, there's going to be a solution for it so it shouldn't be an impediment to licensing reactors. But nobody acknowledges that reality that we are continuing to make waste, and we don't have a solution for it. I think you know, that's just become almost accepted that everyone has their head in the sand.

Cindy Folkers: Moderator

Okay, so the next question, ***what would the impact be of the climate crisis on nuclear plant operations, such as extreme weather, flooding, etc.?***

Mark Z. Jacobson: Panelist

I'll try to answer that. I mean, we've already seen nuclear plants shut down, particularly in Europe, because of high water temperatures. And that's just going to increase and there was, in fact, a study and looked at this issue of what house future climate going to affect nuclear output. And if I recall correctly, it's as expected you expect for reactors to go down more often. I mean, this is part of the reason last year in France, the capacity factor of all 56 reactors over the entire year of 2022 was 56% or 52%. I mean, part of it is because they have an aging fleet, and they required certain amount of shutdown. But in addition, there are also breakdowns but then a portion of the shutdowns were due to higher water temperatures. And this is a problem that's only going to get worse. I don't know any other way to say that it's just going to be a problem we're have to continue dealing with.

Dr. M.V. Ramana: Panelist

I just add one more thing apart from sort of all the operational challenges there.

This also results in financial challenges, because all these energy shutdowns means that a they are not generating electricity and revenue during that period. But they also have to buy replacement power and, and the chat throw a link to a paper that me and a couple of colleagues wrote on this particular issue.

Cindy Folkers: Moderator

This next question, thank you for your responses, this next question sort of speaks to more public opinion than it does to science specifically, but it's regarding the ***catastrophes like Fukushima and how they squelch nuclear growth? If so, do you think that nuclear powers future will always be vulnerable to public opinion? And what this person who asked the question calls ‘rational fears’? And I guess what I would like to hear an answer to is the extent to which you think public opinion should absolutely be part of or not part of a decision to have nuclear technologies?*** Thank you.

Mark Z. Jacobson: Panelist

I think the issue of meltdown is a serious issue.

One and a half percent of all nuclear reactors ever built have melted down to some degree. That's just manifested in public opinion, the actual reality of problems mean, weapons proliferation is another major problem. The multiple countries of the world and develop weapons secretly under the guise of civilian nuclear, commercial nuclear energy programs as research programs. And so yes, I think that, to the extent that the public opinion is reflecting the reality of dangers of nuclear power that are being swept under the rug, basically, that I think that's important to hear public opinion on this issue.

Dr. M.V. Ramana: Panelist

Yes, and then if you want to talk about being in a democracy, then public opinion ought to manifest itself in decision making.

Dr. Gregory Jaczko: Panelist

No, I'd say I mean, I also think that there is a perception that that's true, but I'm not sure that if you truly correlated public reaction to accidents with the long term trajectory of the industry, I don't know that there's a correlation between those, you know, we have an anecdote. We'll talk about, you know, we'll talk about Germany after Fukushima, as a country that decided to change direction. But some of that was already in the works in Germany anyway, there was perhaps an instigating event, but in the US, there was almost the opposite reaction, which was to move forward with reactor construction. And that was at the time of the so-called nuclear renaissance.

I don't know that there actually is a correlation between kind of public perception following accidents. And what happens with the nuclear industry, again, you could look at the US accident at Three Mile Island, and make arguments about—and in fact, in some of these films that I mentioned, there are statements to this effect, that Three Mile Island led to the kind of the whole thing of the nuclear industry, and it didn't. More than 50% of the reactors that had been built in this country were built after the Three Mile Island accident. So you know, I think it does have an impact. But I have yet to see where it actually correlates to really having a meaningful impact on the industries, which is probably a broader statement about our democracies and how our democracies work than it is necessarily about whether that opinion matters.

Cindy Folkers: Moderator

Thank you so much for weighing in on that, Greg, I actually want to pull a thread that Mark mentioned, and that was proliferation, to unpack for us the danger of that with the current fleet that remains open and with the future fleet if they actually get built. And then we will take our final question.

Mark Z. Jacobson: Panelist

Well, I'll just comment on the dangers of small modular reactors, because they're small. There are plans to ship them around the world. And you know, they're on the order of 30 countries in the world that have nuclear energy facilities, but there is a total of around 200 countries in the world. Imagine. And so far, like at least five countries have developed weapons secretly under the guise of civilian programs or research reactors. Imagine sending out small modular reactors around the world. This just makes it easy to either harvest plutonium or an enriched uranium more or two as a reason to import uranium to them and secretly enrich it.

You know, the chances are that there'll be additional countries that might want to develop weapons under the guise of using small modular reactors. I think it's a greater weapons proliferation risks, the small modular reactors. But it's an existing risk if just sending new I mean, if new reactors go into different new countries.

Cindy Folkers: Moderator
Ramana, I'm going put you on a bit of a spot, would you like to comment?

Dr. M.V. Ramana: Panelist

Yes, I think there's sort of two things. One is, yes, definitely, there is the element that when countries get a small modular reactor or any other reactor for that matter, they have access to the materials that can be made into nuclear weapons.

But I also sort of reflect on the fact that when a country decides to build a nuclear power program, then they also have to do two things, they have to train a large number of people in the kinds of skills that are required to build operate nuclear reactors. And many of these skills are transferable to making weapons as well, as well as create an institution, typically some kind of Atomic Energy Commission, or something of that sort, whose interest is to sort of promote this technology. And going by the one country that I have studied extensively, which is India, what we found there was that the Atomic Energy Commission there at some point, realized that, you know, it was the building nuclear power plants itself was not enough for it to be able to keep its hold on political power and financial resources, and therefore decided that at some point that, you know, building nuclear weapons is another way to get at the sport. And now it has this wonderful argument of being able to use either nuclear energy or nuclear weapons, as in when the occasion sort of demands itself.

This is something which is I'm talking about India, but there are other countries where you can see exactly the same pattern. And you can see that also in the United States, when, for example, the Trump administration came to power, a lot of people sort of went round and saying, Well, we can't appeal to the Trump administration for nuclear power because of climate change.

They immediately start making the argument that nuclear power is great for security, we have to maintain our submarines, we have to find jobs for people who are in the nuclear, navy, and so on and so forth. Let me say that in the UK as well, when the Trident submarine was sort of being built that was used as an argument for subsidizing Hinkley Point.

This is a connection that goes not just technical, but also is political.

Cindy Folkers: Moderator

Thank you so much to all three of you. We're going to have our final question now. And then I will close out the webinar. The question is, ***do our politicians not know this information that nuclear is too slow, too expensive and too problematic to solve the climate crisis in time? Are they ignoring it for political reasons?*** So again, this is asking you to remove your scientific hats, and sort of look at what's going on in the political realm. Thank you very much.

Dr. Gregory Jaczko: Panelist

Mark, you want to go first, I'm happy to go first and kind of work. Look I mean, you know, I've been in the middle of those things. It's financial. Most members of Congress are not expert on every issue. And they have to deal with every issue the country faces. So not all of them can become experts in nuclear power, they will say, inordinately get exposure to information that talks about the benefits of nuclear power. And the people who have access our people who have resources have money, you know, all the politics of power. I mean, that's what's happening, because the facts are pretty clear.

This is not a viable strategy for climate change.

This may be an aspirational solution for climate change, but it is not a viable strategy for climate change today. You could have argued 15 years ago had the nuclear renaissance been successful, it would be today because we would be on the verge of the ability to build dozens and dozens of reactors and, you know, perhaps have dealt with cost issues and all these things.

I think they don't have access to enough information. I think they're not getting the right information, and the industry is not providing them with accurate information.

Mark Z. Jacobson: Panelist

Well, I think the support for nuclear, like coal or oil in Congress is proportional to the number of lobbyists and the number of lobbyists is proportional to the penetration in the of the energy source in the US electric power grows.

Nuclear still has a significant portion of electric generation in the power grid. It has a lot of lobbyists that may convince a lot of policies makers. There are certain policymakers also that they're not going to change their mind. But there are a lot, as Greg said, that don't have the right information.

They're not aware of how long it takes to build a reactor and they're not aware of the full costs. They're not aware that they're not zero emissions. I mean, there's a lot, and you see this everywhere, that everybody says of nuclear zero carbon. They pretend it matches demand. They say it's baseload. And then the idea that baseline somehow matches demand is implicit there, which it doesn't, so you need backup for. They try and pretend it doesn't need backup; it doesn't cost much, it doesn't take long to implement. Then there are people who provide misinformation. ‘Oh, there's never been any health damage or death due to any nuclear meltdown, there's never proliferation risk. Your uranium miners never had lung cancer problems underground.’

There's a lot of misinformation and lack of solid information that gets to policymakers and as a result, they support not only nuclear, but there's also this same problem with carbon capture, direct air capture, blue hydrogen, electro fuels, biofuels, there's all-of-the-above-policy a lot of people are pushing. ‘Let's just try everything, hope something works.’ And right now, we just don't have enough time to try everything. And we have limited amount of money. And the problem is so huge, we really need to focus on what works. And that is really lost. Even on the current administration. I mean, 40% of the inflation Reduction Act, money is being spent on technologies.

Not only is it small modular reactors, but carbon capture blue, hydrogen, etc, that are completely useless for helping solve the climate problems. I mean, 60% of the funding is spent on good things. But that this is an endemic problem about people just pushing everything. And because there's no financial interest in it, or because they're ever perceived, though people just say things that are just not backed up by science, or based on old science.

Dr. M.V. Ramana: Panelist

I'll just add one. I think Greg and Mark have already covered all the points. But to sort of Mark's point about, you know, politicians trying everything, I have a couple of things to say. First is, you know, this was an idea that was said in the old BBC serial as prime minister, for those of you who may have watched it, there is something called a politician's logical politician syllogism, which is we must do something, this is something before he was doing this. I think that's the idea that, you know, because people say this is a climate change solution, you should do it.

The one thing is that it's not also the case that they are trying out everything, and then trying to figure out what works and scale that up, right. In some sense, the nuclear renaissance talk in the early 2000s, was the experiment. The experiment ended in failure. We should have abandoned it at this point. But that's not happening. In some ways, there is this perception or this need to be perceived to be acting and supporting everything and not be open to criticism from certain sectors, including the nuclear sector. That they are not supporting enough and doing enough on climate change by not supporting their sector.

Dr. Gregory Jaczko: Panelist

And maybe I could just, I'm sorry—were you done? I didn’t want to cut you off. You're done. Come on, Just wanted to end on a positive note here to these climates. I mean, well, maybe it's a negative note. But the reality is the climate change is solvable. All these metrics and goals that the IPCC talks about, that scientists talk about. They're all solving the market shown. They're all solvable with everything we have today. What's the challenges are political challenges and you see it manifested in the fact that we're even having, you know, a webinar to talk about this issue of nuclear and climate change, because it's just not it's not a real solution. You know, it's a mechanism for the industry to preserve itself. It has nothing to do with solving climate change. But yet the actual solutions are out there and achievable. Deployment within 10 to 15 years of 100% solution that Mark talks about is within the financial means of this country.

The technological and bureaucratic means that this country. It is simply pushing up against the political opposition to that because of industry trends, you know, trend translation. The gas industry will go away, the EPA’s Office of Air will go away, right, because we no longer are producing the things which are some of the main contributors to the air issues and health issues that Mark has talked about. I mean, we're talking about such a fundamental change to the way that our country works and operates that it's engendering opposition from the insurance industries. And that's what you're saying. It's not a technical, financial or bureaucratic challenge.

Cindy Folkers: Moderator

On that note, thank you very much. I will conclude the webinar with some closing remarks. Thank you all for attending this briefing. And I would especially like to thank our wonderful and informative speakers. We will be posting the speaker slides briefing resource documents and the recording on Google Drive, which you can find at the link pasted into the chat. This briefing was organized by the National decommissioning Working Group, a national network of regional and network of national, regional and local NGOs. It is sponsored by the Samuel Lawrence foundation and co-sponsored and supported by Nuclear Energy Information Service, the Sierra Club, Atlanta and lower Hudson chapters and numerous members of the Decommissioning Working Group network. For more information on the working group and this briefing, contact decomworkinggroup@gmail.com journalists can also contact Stephen Kent at skent@kent.com. And those email addresses are going to be posted into the chat. Thank you all very much and have a good evening.