CRISIS AND OPPORTUNITY: THE FUTURE OF NUCLEAR ENERGY

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THE ASPEN INSTITUTE
ENERGY & ENVIRONMENT
PROGRAM

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Published in the United States of America in 2017 by The Aspen Institute

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FOREWORD

Nuclear Energy has been a cornerstone of the US electricity system since its inception in the late 1950's. Now, with inexpensive natural gas, renewables such as utility scale solar, and onshore wind, nuclear power is struggling, and more and more plants are announcing early retirements. While there are many policy options to help existing nuclear, there is no silver bullet. Many of these options are spread out among a variety of federal, regional, and state authorities. However, as a matter of national and climate security, it is important for the US to regain its global leadership in the civilian nuclear energy sector. This will not be easy, and there is not much time left.

Dan Poneman, the 14th Deputy Secretary of Energy, and now the CEO and President of Centrus Energy Corp, and Joseph Dominguez, the Executive Vice President of Exelon Corporation, graciously dedicated their time and considerable expertise to make this roundtable as great as it was. The excellent discussants and participants made the agenda come alive with discussion and debate and made this among the best dialogues we have held in Aspen.

The Institute acknowledges and thanks our sponsors for their financial support. Most have been participants and supporters for many years. Their generosity and commitment to our work ensures the Roundtable can continue to provide valuable high-level discussion.

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EXECUTIVE SUMMARY

The future of nuclear energy remains as exciting and challenging as it has ever been. The challenge is perhaps most acute in the present, with the existing U.S. nuclear fleet in crisis, and the fate of future nuclear builds in the US hanging in the balance. Some existing plants have announced impending closures or their intent to close absent some policy solution, while others are simply under financial stress. The economics are challenging, as nuclear units' costs are higher than wholesale market prices almost everywhere. The diminishment of the existing fleet could have serious impacts on reliability, resilience, carbon emissions, jobs, and the nuclear Navy supply chain. The industry has been somewhat successful in trying to preserve existing plants, as evidenced by the progress made last year in New York and Illinois, but that progress hasn't continued into Ohio this year, due in part to heavy lobbying by interests seeking to expand markets for natural gas. The Trump Administration appears to recognize the gravity of the situation, as highlighted by the recent Department of Energy (DOE) resilience study. While there are some efforts underway at DOE to help the existing fleet, it is really the Federal Energy Regulatory Commission (FERC) that can be most impactful in competitive markets, including addressing energy price formation issues in wholesale markets and devising capacity market solutions that value other attributes the existing fleet provides.

If the United States manages to retain much of its fleet, there is an additional challenge in finding a pathway that enables new nuclear to come into the market in the relatively near future. New civilian nuclear plant construction in the United States is a rarity, which means the few that have been tried have basically been first-of-a-kind builds that have been far over budget and behind schedule. VC Summer was cancelled, and Vogtle remains in jeopardy. New build in the United States is in need of federal and state policy support, which could include loan guarantees, production tax credits, power purchase agreements, clean energy standards that include nuclear, or a meaningful price on carbon. If the United States loses its existing fleet and fails to build new Generation III or III+ reactors, the country may never get to the stage of deploying advanced reactors.

Advanced nuclear technologies are where a lot of the excitement lies with regard to the future of nuclear energy. Small modular light-water reactors are probably the furthest along, with the design certification application for one already underway at the Nuclear Regulatory Commission (NRC). Costs for advanced nuclear are expected to be significantly lower than for conventional nuclear per megawatt, but the market is very clear that advanced nuclear will have to be competitive with natural gas, which is why some developers are focusing on designing for cost competitiveness. Advanced nuclear represents an opportunity to take advantage of America's strength in innovation; the United States could unleash a tidal wave of nuclear innovation that dominates the global landscape – but it has to do more, and do more faster. This could include a nuclear innovation support program for the 21st century (including resistance to the Administration's desire to focus all federal research on early-stage R&D), protecting DOE's loan guarantee program, new models of public-private partnerships, developing a versatile test reactor, and advocating for nuclear deals abroad. The NRC, meanwhile, has to evolve to better balance benefit and risk and improve its performance in reviewing new reactor designs; it should consider creating a separate team and framework for advanced reactors that can reset the NRC's willingness to take risks.

Whether dealing with advanced or current reactors, the nuclear fuel cycle represents yet another challenge for the United States. The country does basically no uranium mining anymore, has only one old facility for conversion, and now lacks U.S.-owned and -controlled enrichment capacity – although the country is at least a leader in fuel fabrication and

advanced accident-tolerant fuels. The United States also is desperately in need of interim and permanent repositories for waste, though an additional option is development of advanced fast reactor technologies that could consume waste and close the fuel cycle. The atrophied state of U.S. fuel cycle capabilities has potentially significant geostrategic and non-proliferation ramifications. The United States must reestablish its fuel cycle capabilities and reassert nuclear leadership.

Given the challenges facing the current fleet, new build, and the fuel cycle, the industry has to figure out how best to communicate about the present and future of nuclear. The public perceives nuclear power as risky and associates it with the accidents at Three Mile Island, Fukushima, and Chernobyl, yet the industry may also be overdoing its messaging to the public on safety. The challenge for the industry is to start constructing a different public narrative focused on what is interesting, exciting, and compelling about nuclear, such as innovation. In the near term, communications with policymakers may be more effective than general public messaging. Reaching policymakers requires simple and clear messages and asks. Policymakers' excitement around advanced reactors could be used to help pull along the existing fleet and some new build, and there is potential to get bipartisan support for nuclear power.

The sense within the industry is that it probably has less than 5 years (perhaps less than 18 months) to figure out how to solve the challenges facing nuclear power. Nuclear advocates have to figure out the policy asks essential to the industry's near-term survival, as well as what is needed in the medium and long term. The White House review to revive nuclear energy represents an opportunity. One short-term focus could be getting a high-level national priority statement on nuclear power out of the White House (e.g., in a State of the Union speech) that sets forth objectives broad enough to be inclusive and specific enough to provide direction. Other short-term policy priorities could include actions to preserve and sustain the existing fleet, loan guarantees, extension and reform of tax credits, reform of 123 agreements, creation of a high-assay low enriched uranium reserve, and regulatory reform to facilitate the licensing of advanced reactor designs. Medium-term priorities could include actions at FERC to reform wholesale markets, multi-year public-private partnership funding commitments, and progress on interim and permanent waste repositories. Longer-term asks could include many things, including potentially a national carbon price. Many of these priorities will require significant funds, but government investments in nuclear have been far too small for the problems the country faces.

Particularly because it is so difficult to envision popular support for nuclear changing much, the industry cannot forsake coalition building if it wants to achieve its policy goals. There are already ecosystems around concerns such as clean air, climate change, technological leadership, and national security, and they have to be educated on how nuclear can help their agendas and on why they should have a nuclear element in their messaging. There are opportunities for the industry to build relationships with climate advocates, given the role nuclear can play in deep decarbonization, but the industry will face some serious headwinds given the appeal of the vision of 100% renewable energy, the perception that the nuclear industry is never vocal in supporting climate policies and regulations, and the anti-nuclear leanings of climate philanthropies. There is also coalition building to do among nuclear advocates to elevate coordination to a higher level. There is a need for an integrated strategy that enables more coordinated, strategic, and effective action and that nurtures potentially supportive allies, but there needs to be an organizational umbrella across the issue areas that can make sure action is happening where needed at the federal and state levels. There is also a need to boost funding for the non-industry nuclear advocates. The enhanced coordination can help nuclear advocates achieve wins quickly in order to start showing momentum.

THE EXISTING NUCLEAR FLEET

The future of nuclear energy remains as exciting and challenging as it has ever been. If the United States loses its existing fleet, however, the country may never get to that exciting future.

THE CRISIS IN THE EXISTING FLEET

The U.S. nuclear fleet consists of about 99 reactors, but the fleet is in crisis and could see a serious decline in numbers over coming years. Within the existing fleet, there are some plants that have announced closings, some that have declared their intent to close absent some policy solution, some that have concerns related to market conditions, and some that seem to be in good shape. In the last 4 years, 6 reactors have closed, while 12 have announced early retirement and 6 were preserved by state actions. There are 12-20 plants that are hanging by a thread. Even retaining a significant share of those in financial stress will still result in a loss of some nuclear capacity, perhaps 20%. If there is no further state or federal policy support, half of the fleet could be lost. If a significant number of plants do not go through subsequent license renewal, the fleet could be reduced to less than 20% of what currently exists. The profile of the existing fleet over the next decade will be shaped by the ability of marginal plants to remain viable. Civilian nuclear power technology could wind up being adopted, deployed, licensed, licensed again, and then phased out all within the space of a human lifetime.

The economics are challenging, even for units that previously would have been thought to be operating in the most lucrative merchant markets. The problem had been focused on single sites with single units, but it is now migrating to dual (or more) unit sites as well. Large dual nuclear units, large single nuclear units, and small single nuclear units all have costs higher than market prices almost everywhere; only in New England can larger sites even come close to covering their costs. While nuclear power is not alone in encountering problems in wholesale markets, wholesale prices are expected to continue their downward trend, so the picture for nuclear is not expected to look any better next year. Over the past year, some companies have essentially made the decision to exit merchant nuclear operations.

The loss or serious diminishment of the existing fleet would have a range of implications, such as impacts on reliability and resilience. With regard to climate change, nuclear power provides two-thirds of the zero-carbon electricity in the United States, so the loss of the existing fleet would raise greenhouse gas emissions if replaced by fossil fuels, such as natural gas. In addition, if one wants to keep alive the long-term possibility of a hydrogen economy, preserving the existing nuclear facilities makes a lot of sense, as they produce heat and provide inexpensive electricity at night to split water.

There are economic and security implications as well. Among the lower 48 states, 44 have companies in the nuclear supply chain, providing nuclear products and services. A shutdown of a plant in one state sends ripple effects through others. The same companies also supply the nuclear Navy; as the supply chain gets weakened from civilian plant closures, there could be risk factors for the Navy, potentially reflected in price or availability. In addition, the

nuclear supply chain is not just products and services but also human capital, and nuclear engineers are sensitive to longer-term market developments. After the Three Mile Island accident, the number of U.S. nuclear engineering graduates dropped for a couple of decades. While the number of graduates in nuclear engineering has gone up substantially over the last decade, it may be at another peak, given the wave of retirements.

EFFORTS TO SUPPORT THE EXISTING FLEET

The industry has been somewhat successful at trying to preserve existing plants, as evidenced by the important progress made last year in New York and Illinois, but that progress slammed to a halt this year. The one major piece of state legislation attempted in 2017 to support the existing fleet – in Ohio – failed due to a confluence of factors, including deep distrust of the utility seeking to keep its plants online and the fact that arguments about climate risk do not play nearly as well in the Ohio legislature as in New York and Illinois. There was also heavy, sophisticated, well-funded, and very effective lobbying by the American Petroleum Institute (API), which has come out more aggressively than ever before in the political arena against nuclear supports. API sees the retirement of nuclear power plants as a great opportunity for natural gas; with oil markets diminishing, dominating electricity markets with natural gas has become a greater goal. API sees the nuclear industry as an easy mark, as it is poorly organized, has proven unable to rise and fight effectively, and does not have strong coalitions and alliances.

Supporting the existing nuclear fleet is a national problem, and it is tricky to address a national problem with state-level policy.

Other states have been grappling too with whether to intervene to help particular nuclear units, and utilities with nuclear plants have been arguing before state commissions and policymakers that cheap, reliable, and zero-carbon nuclear power is in the best interests of customers. Utilities, however, are not strongly pro-nuclear. At a certain point, utility executives will reach a level of political and financial punishment where they just decide to cut their nuclear plants loose, and there are compelling strategic rationales for doing so, especially in deregulated markets. Many of the new generation of utility CEOs come from a finance background and are looking at the economics to make hard decisions on behalf of shareholders; when utilities announce the closure of a nuclear plant, their stock price goes up. In addition, utilities and regulators are getting pressure from system operators about the tensions between what is happening on the distribution side – with regard to renewables and distributed energy resources that are reducing the need and load for traditional baseload resources – and what is happening on the wholesale side, where operators are getting calls to reinforce the baseload generation fleet.

Supporting the existing nuclear fleet is a national problem, and it is tricky to address a national problem with state-level policy. There is a need for national leadership on the issue. The Trump Administration appears to recognize the situation, as highlighted by the recent Department of Energy (DOE) resilience study, and seems to be looking for ways to support nuclear and coal baseload assets. Obviously, the Administration is not focusing on climate change, but rather on resilience, fuel diversity, and energy price formation issues in wholesale markets.

While there are some efforts underway at DOE to help the existing fleet – such as working with industry on developing technical bases for subsequent licensing extensions (from 60 to 80 years) and on developing accident-tolerant fuels that can enhance safety and reduce operating costs – the opportunities for the existing fleet are located much more in the nerdier, economics-heavy halls of the Federal Energy Regulatory Commission (FERC). FERC can take actions, both small and big, to help the existing fleet in competitive markets, but there are also complaints before FERC that could be detrimental to the gains nuclear power made last year in some states.

The big solution at FERC would be a carbon price. Existing nuclear plants operate at costs below those of a combined cycle gas turbine with any reasonable carbon price in the market. (They are also well below offshore wind farms that come in, optimistically, at $170/MWh and could more realistically be $250 or $300/MWh.) A lot of

legal analysis suggests the Federal Power Act gives FERC the authority to accept a proposal from a market operator to include in dispatch a representation of carbon. New York has gotten pretty far down the road in terms of design, and PJM has put forth a concept paper about incorporating a price of carbon in its dispatch, but there is still a ways to go. A carbon price also seems incredibly unlikely in the current political climate.

A smaller solution at FERC involves energy price formation, specifically fixing problems that wholesale markets have had all along but that did not matter as much when there were fewer zero-marginal-cost resources on the system. Nuclear power operators face negative pricing as a result of subsidies paid to wind and solar generation; wind can run at negative prices thanks to the Production Tax Credit, so during off-peak hours, wind units with zero (or negative) marginal cost are setting the price. Nuclear units that are inflexible and cannot ramp thus earn nothing or lose money during those off-peak hours, which brings down the overall economics of the units. It is hard now for nuclear to compete in a marginal-cost marketplace, and cheap natural gas has made the situation more acute. If, instead, all the operationally-constrained units were allowed to come into the market at their marginal costs, and the price was set at the level of the most expensive unit the system needs in order to keep running, the super-low and negative price situations would be avoided. Prices would still be below the costs nuclear power needs, but on an around-the-clock basis, it would at least provide economic uplift of maybe $1-5/MWh, which could be important for units on the bubble.

FERC could also address the need to value other attributes the existing fleet provides, which involves more of a capacity market solution. Issues such as energy security, energy diversity, resilience, zero carbon, and international leadership are not modeled at the individual project level, not included in financial models, and not valued by the market – which means the public is benefiting from the existing fleet without paying for all of that benefit. For instance, reliability risks related to natural gas distribution disruptions should be valued in the marketplace, but they currently are not. FERC could read the Federal Power Act pretty broadly to bring attributes into market design. (To an extent, this is what happens in fully integrated markets.) Some of these attributes, however, may conflict; focusing on diversity or perhaps resilience, for instance, could support coal plants as well as nuclear, which could run counter to efforts to advance zero-carbon attributes. On the other hand, capacity markets could give money to coal to be around in case it is needed, but a different system of dispatch (e.g., one that accounts for carbon and/or criteria pollutants) could mean coal almost never actually gets dispatched.

Indeed, one could envision a system where plants are not compensated through energy markets based on marginal price dispatch at all, but rather only through a number of markets for capacity and other services and attributes, with some central dispatch function based on some set of criteria. One approach could be bifurcated capacity markets, which could come in lots of variations. The core idea is that instead of stacking all units and picking units based on price, there could be two different demand curves, one for all the units that are eligible and one for the attributes that have been determined by FERC to be needed in the fleet. Only the resources with the desired attributes would bid on that demand curve, with a price set for them, while the rest of the needed capacity would come from the other demand curve. Whatever the precise form, a market construct is needed that better values existing nuclear generation assets. Such constructs, however, are becoming increasingly like Rube Goldberg machines and are essentially re-regulation in a different form, which makes some people uncomfortable. In addition, big corporate buyers of renewables may see such reforms as raising their rates.

Not everything before FERC represents potential solutions for the existing fleet; there are risks at FERC as well. Some people have been up in arms over the state subsidies for nuclear plants, claiming they subvert the market (and seemingly ignoring the massive state supports for renewable energy). In addition to litigation, there are complaints pending at FERC that could be quite harmful to the advances made last year in states; FERC could wipe out the benefits from those state policies. Similarly, PJM is considering a solution that would put subsidized resources into capacity markets at their unsubsidized prices, but the proposal would exclude many things (e.g., most supports for renewables) from counting as a subsidy, basically leaving only nuclear power getting kicked to the back. People seem to be afraid of taking on renewables, while nuclear appears to be an easier target for critics; there as not as many voices supporting nuclear.

NEW BUILD & ADVANCED REACTORS

If the United States manages to retain much of its fleet, nuclear still has to add new plants if it wants to maintain its share of the electricity mix over the next few decades. Decisions affecting the power mix mid-century will be made soon. To continue enjoying the benefits of a significant share of nuclear in the U.S. mix, there has to be a pathway found that enables new nuclear – whether current generation or advanced reactors – to come into the market and be commercialized in the relatively near future.

NEW BUILD

There are 30 nations that depend on nuclear energy, and 51 new reactors are under construction globally. Unlike many other places in the world, however, new nuclear power plant construction in the United States is a rarity – at least with regard to the civilian market. (The United States does have a reactor manufacturing business, but only really in terms of manufacturing a couple of new nuclear reactors annually to supply the nuclear Navy.) While Watts Barr 2 construction was completed, VC Summer was cancelled, and Vogtle remains in jeopardy (as numerous caveats were put in place for moving forward with it). The issues during construction of Summer and Vogtle that led to them being far over budget and behind schedule are closely tied to trying to do something again after having not done it for 30 years. They were basically first-of-a-kind builds.

New build in the United States is in need of federal and state policy support. Never in the history of nuclear power has a project been project financed; commercial banks are not coming into the space at all. It is also just generally hard to finance anything really expensive in deregulated markets right now, whether nuclear, carbon capture and storage, or other big energy projects, as the economics are not favorable with regard to returns or risks. (In contrast, it is very easy to finance something like a 2 MW solar plant because it is small and has a guaranteed market.) It is not clear that anyone but the government will assume the risk of a first-of-a-kind construction project that costs upwards of $10 billion. Economic policy enablers could include loan guarantees, production tax credits, and power purchase agreements. Clean energy standards that include nuclear power would also help, as would a meaningful price on carbon, whether at the state level or (someday) at the national level. In addition, it is possible that FERC efforts to address market structure and pricing reforms, such as finding ways to monetize resilience and reliability, would help both the existing fleet and potential new reactors.

There has to be a sense of urgency, at least for climate reasons. To maintain a 2°C or even a 3°C planet, net emissions have to reach zero by mid-century or a little after, assuming there is an ability to suck additional carbon out of the atmosphere. The power sector has to get to zero emissions faster, as it will be relied upon to electrify transport and, to an extent, industry. If the world could deploy nuclear power at the rates that France and Sweden have, nuclear power could theoretically accomplish all the needed decarbonization within 30-40 years (not that there should be an all-nuclear grid). When nuclear technology scales, it deals with a lot of carbon, and deployment can be rapid. In 1943, the United States built a graphite reactor in 9 months; that serves as a reminder of what the country can accomplish when

it faces compelling challenges. Unfortunately, the best global deployment rate is far below what is needed and has to be raised higher. An additional source of urgency is this: if the United States loses its existing fleet and fails to build new Generation III and IV reactors, the country may never get to the stage of deploying advanced reactors.

ADVANCED REACTORS

The American nuclear story is much more optimistic when it comes to advanced nuclear technologies. There are numerous types of advanced reactors and technologies – including fuels, materials, reactor designs, and cooling technologies – and lots of developments on the horizon to be excited about, whether molten salt reactors, small modular reactors (SMRs), new engineered materials (e.g., ceramic composites), or other advanced technologies.

SMRs are probably the furthest along. SMRs are more about the economies of small than the economies of scale. Most aging coal plants are 300-600 MW and have existing infrastructure, and SMRs could go in and replace those generation units. (Many people at those coal plants could also be retrained to work at the SMR plant; not everyone who works at a nuclear plant has to be a nuclear engineer.) The design certification application for one company's SMR is already underway at the Nuclear Regulatory Commission (NRC).

The economics will be a key determinant of whether advanced reactors come to fruition. Companies developing advanced nuclear projects greater than 300 MW estimate capitalized construction costs averaging around $3700/kW for an Nth-of-a-kind plant. This is lower than what would be expected for larger, more complex projects, with the biggest reductions coming in indirect service costs (e.g., offsite engineering, construction supervision, equipment rental, temporary buildings). Plant design standardization – whether partial or high – is one of the primary cost reduction drivers. Financing costs are also expected to be lower compared to a conventional benchmark because companies expect an average construction duration of four years rather than seven, due to needing fewer and smaller buildings, utilizing some combination of modularity and factory- or shipyard-based manufacturing, and implementing other ways of reducing construction scope. The reduced construction schedules could put nuclear back in line with things like gas plants, solar plants, and storage projects that can be built much more quickly than conventional nuclear and are thus easier for utilities to include in their integrated resource plans.

Annual operating costs are projected to be lower as well, dropping from around $31/MWh to around $21/MWh on average. These reductions come from an assumed decrease in the number of operating staff needed due to advanced reactors' plant simplicity and inherent design (e.g., fewer safety technicians and monitors needed). All told, the levelized cost of energy (LCOE) for advanced reactors is projected to be around $60/MWh on average.

The market is very clear, however, that advanced nuclear will have to be competitive with natural gas. Natural gas combined cycle plants in the United States, with natural gas around $4/MMBTU, are producing power at around $45/MWh, and in Asia, where gas is a little more expensive, it is around $50/MWh. Cheap gas is the competition. (There is also the potential for zero-carbon gas to be additional competition, with a Texas demonstration project promising delivery of electricity at about the cost of current conventional gas plants with the bonus of a fully compressed and separated carbon dioxide stream.) Even plants that may be the ultimate from a safety perspective have to get costs down in order for the economics to enable deployment. Some advanced reactor developers are therefore focusing on designing for cost competitiveness with regard to the entire plant, including both the reactor and the rest of the island. They are designing to simplify reactors, eliminate the need for a variety of safety systems, and vastly reduce the amount of structure (e.g., concrete, steel) required.

Lack of investor and customer interest is slowing down the development process for advanced nuclear, but if advanced nuclear developers can stay focused on creating a marketable, competitive product, a lot of financing problems solve themselves. There is a lot of capital in the world looking for profitable investments.

EFFORTS TO PROMOTE ADVANCED REACTOR INNOVATION AND DEPLOYMENT

Advanced nuclear represents an opportunity to put the United States back in a leadership role, taking advantage of America's strength in innovation. Innovation is a competitive advantage that the United States should embrace; the United States can tap into a privately-driven source of innovation that exists nowhere else. There is a great deal of new interest, investment, and talent going into advanced nuclear, beyond the historic actors in the market, and universities and the national labs can be the foundation for an acceleration of innovation. Moving the right levers, the United States could unleash a tidal wave of nuclear innovation that dominates the global landscape – but the country has to do much more and move much faster to make that happen.

An immediate concern is getting more granular on what a nuclear innovation support program for the 21st century actually looks like. In particular, the nuclear industry and its supporters have to make the argument to the Office of Management and Budget (OMB) that the Trump Administration's desire to focus all federal research on early-stage R&D does not make sense for nuclear energy. There are two valleys of death that government can help bridge. The first is before technologies are proven technically – the early phase work in which the private sector largely does not invest. Long-term, that is an intrinsically governmental role. The second is when the technology is demonstrated but not yet deployed at commercial scale. Usually, it is only after the government has helped bridge that valley and satisfy the risk requirement of commercial viability that private sector investors can come in, lower the cost of capital, and expand the pool of investors. Labs, however, are being directed to limit their program work to really early-stage research, such as proving out concepts, but not to extend the work to component design or assisting licensing activities. Robust resistance is needed to OMB's early-stage guidance. Alternatively, the definition of "early stage R&D" could be expanded to encompass first-of-a-kind engineering and plants; that is still early-stage in terms of deployment, but it is a higher technical readiness level.

The United States could unleash a tidal wave of nuclear innovation that dominates the global landscape.

Protecting DOE's loan guarantee program is also important. For building something like a molten salt reactor, it is not realistic to go to a bank and ask for billions of dollars in debt. The utility-scale solar market was enabled by DOE loan guarantees because no one in the private sector would provide credit; advanced nuclear is in a similar situation. Programs such as loan guarantees were essential in getting SMRs to where they are today. The core idea is to carry companies through a risky period of development, get technologies into operation, and have a market. The issue is less who will finance the fifth project as who will provide debt for the first; after the first few are built, regular finance is more willing to come in. DOE's program was designed to overcome a market failure, but if its budget is eliminated as proposed, getting it back will be difficult. People outside of government have to make a forceful argument for what the role of government ought to be in this arena and have to make sure Congress is clear on the implications of its actions.

There is some action in Congress on these fronts, particularly in the form of the Advanced Nuclear Energy Technologies Act, proposed legislation with bipartisan cosponsors in Senators Flake and Booker. Recognizing the need for significant DOE cost-share given that private sector innovators are looking at multi-billion dollar gaps to an actual demonstration project, the bill would direct DOE and OMB to think about building some big public-private partnerships to demonstrate different types of reactors. The bill would also establish some aggressive cost and performance goals (e.g., price points) for demonstrations to be chasing.

Public-private partnerships will clearly be needed, though a different model than was used to develop nuclear power in the 1950s. There is no need to bring back the 1950s and 1960s, but government and industry working together can make technologies succeed. Anniversaries can be good windows for talking to Congress – emphasizing the history in addition to the contemporary need – and the 60th anniversary of Shippingport can be used to tout the importance of public-private partnerships and the benefits of nuclear energy.

There could be many possible models. There could be a huge public corporation, as DOE has suggested in the past, though there appears to be little enthusiasm for that idea. There have been one-off Funding Opportunity Announcements with cost shares and lab resources, but that is a bespoke structure that provides little forward-looking predictability about whether more would be available. Another concept would be some kind of Advanced Reactor Consortium, which would have buyers of plants influencing decisions about which technologies to fund. Others could be public-private tax treatments (e.g., investment tax credits, master limited partnerships) and the loan programs at DOE, which could help unleash huge pools of lower-cost capital. These likely are not mutually exclusive options.

Clearly, funding has been and remains a core part of the government's role. It may be time to rethink having the U.S. budget for nonproliferation be twice as big as for nuclear innovation; that budgeting is predicated on a model of keeping the nuclear cat in the bag around the world – but that cat is out of the bag. Sustainable, predictable government funding, preferably focused on concepts as opposed to specific technologies, is important for building the credibility and capabilities of advanced nuclear. Some have proposed having the government fund the majority of the upfront costs involved in licensing and design, with the private sector providing the innovation, intellectual property, and workforce upfront and then bearing the costs starting at the construction phase. That would retire a great deal of upfront risk for developers, but the lack of upfront cost-share could also be problematic, as it could fail to weed out a lot of the "companies" advancing new designs that are really just two people with a PowerPoint presentation.

Sustainable, predictable gov-ernment funding, preferably focused on concepts as opposed to specific technologies, is important for building the credibility and capabilities of advanced nuclear.

Throwing tons of money at advanced nuclear presents a challenge, though, given the current anti-spending political sentiment. There are other public-private partnership models that do not have to involve cutting a huge check but that can still create traction. Key ways the national labs can help deploy nuclear technologies more rapidly is by focusing on materials manufacturing, sensors, and modeling and simulation capabilities; these can be incredibly powerful in helping the industry get ahead of the curve. DOE's Gateway for Accelerated Innovation in Nuclear (GAIN), for instance, recognizes that DOE has world-class capabilities – whether experimental, modeling and simulation, computational, or human capital – that it is trying to open up to the private sector in a streamlined, useful way. The GAIN program came about because nuclear advocate non-governmental organizations (NGOs) met with DOE and the labs to identify specific needs other than piles of money, and the NGOs' sustained interest and encouragement pushed the White House to allow DOE and the labs to move forward. Over the last two years, GAIN has competitively awarded $7 million to small businesses in the advanced reactor community to support 21 projects, but the access to DOE may be more valuable than the dollar value. (That said, in DOE's Nuclear Energy Enabling Technologies program last year, none of the grants went to industry; instead, all went to labs or universities.)

There are other needs that DOE can satisfy as well. For instance, the advanced reactor community needs a versatile test reactor, including fast test reactor capabilities, that can help a range of advanced reactor designs test concepts and materials. DOE is also investigating use of federal power purchase agreements (PPAs) to support the first deployment of advanced reactors, though the how of government PPAs matters, not just the dollar figure; the government has to be careful not to distort the market.

In addition, DOE, along with Congress, the ExIm Bank, the State Department, and others, could do a better job of advocating for nuclear deals abroad. Countries looking to purchase nuclear plants do not have the ability to finance them themselves, so even if the United States develops the best, most innovative advanced nuclear technologies, most countries will take the cheaper, complete package deals being offered on a government-to-government basis by Russia and China as part of broader, multi-sector bilateral relationships. It is not clear that American technologies being the best will carry such value with it that other countries would be willing to pay more. The U.S. government has to be leading the charge and getting sites for nuclear technologies. Perhaps some kind of ambassador-at-large position could be created at the State Department to advocate for civilian nuclear, given how much impact nuclear power has on other diplomatic issues.

ROLE OF THE NRC

The NRC is seen as the gold standard of nuclear regulation, but this has benefits and drawbacks. For instance, given its credibility, the NRC plays a big role in the competitiveness of U.S. nuclear on the global export stage; although regulators around the world have been partnering with Russia given terms that were hard to turn down, they would prefer the NRC as a partner. On the other hand, being the gold standard on regulating risk can lead to people dutifully doing their jobs in a way that creates a big, bureaucratic machine that stops anything new from getting built.

The NRC has to innovate and evolve. It cannot rest on its laurels of being the gold standard. Members of the NRC staff are strong on subject matter expertise, but they are lagging the pace of change happening in the industry. For one thing, the agency needs better approaches to risk. Many staff see their job as risk reduction, and that is the lens through which they operate, but there has to be a balance between benefit and risk. Relatedly, the NRC has to improve its performance in reviewing new reactor designs. The NRC designs the schedules for reviewing reactor designs and then blows by them by orders of magnitude; the process should not get sidetracked by focusing on unimportant areas. Taking 11 years to review a light-water reactor design is unacceptable. Reforming the licensing process for new reactors – moving to a risk-based licensing approach – is essential.

The NRC needs a regulatory framework that keeps nuclear power as an option.

There is one SMR now docketed at the NRC, and its review is on or ahead of schedule. The NRC tends to be very prescriptive, but there are many things a large reactor has that SMRs do not need. In the absence of regulations that address such technologies, the NRC has to lean on the exemption process to avoid making applicants check boxes on things that do not apply to them. There is cultural resistance within NRC, though, to exemptions.

Light-water reactors are what the people at the NRC know, so SMRs could help pave the way for non-light-water advanced reactors. Advanced reactor designs, which will bring unprecedented safety levels, could be an opportunity for a refresh at the NRC on what is considered safe, but the advanced reactor community will be challenged by the fact that the NRC lacks experts who will understand the new technologies it is bringing in. There is a pendulum that swings between the NRC feeling it can be closely involved in DOE and lab activities without violating its independence and the NRC feeling it is better off disengaging and not knowing; currently, the pendulum appears to have swung to the extreme of not knowing. There is a need to bridge the education gap without compromising agency independence.

The NRC has far more resources than its Canadian counterpart, and yet it is Canada that has shown a willingness to pilot innovative approaches for advanced reactors. The NRC has, though, been thinking about a new framework for advanced reactors. The NRC should consider creating a separate team and framework for advanced reactors that can reset the NRC's willingness to take risks. If the NRC does not bring the right mindsets to licensing, it could take the whole option of advanced nuclear off the table for the United States.

Some argue that the NRC should be more like the Food and Drug Administration in having a joint mandate – to assure both safety and approval – however the Atomic Energy Act already mandates that the NRC is supposed to enable beneficial uses of nuclear. The NRC needs a regulatory framework that keeps nuclear power as an option; advocacy for nuclear power is not the NRC's job, but having nuclear fail to even be an option would be a failure of its role as a regulator. (Furthermore, if the existing fleet retires and new builds do not occur, then the NRC will get much smaller, a lot of the best and brightest on staff will leave, and the NRC may or may not be able to resurrect itself as a world-class regulator in the future if the industry makes a comeback.) Some argue that there should be a specified timeline for reviewing advanced reactor designs (e.g., three years or less); while holding to a fixed schedule for NRC review sounds appealing, it can be dangerous unless at the same time the applicant has to meet a certain level of pre-licensing readiness. A different model might be for the NRC to shift to something more like the Federal Aviation Administration or the Occupational Safety and Health Administration, where working on a fixed-fee basis instead of a time-and-materials basis puts the incentive on the regulator to drive efficiencies.

THE NUCLEAR FUEL CYCLE

The nuclear fuel cycle is broad, covering everything from uranium mining to waste management. The atrophied state of U.S. fuel cycle capabilities has potentially significant geostrategic and non-proliferation ramifications.

MINING, CONVERSION, ENRICHMENT, AND FUELS

The United States does basically no uranium mining anymore, though it has several allies with plenty of uranium. One area worth further exploration is seawater extraction – essentially fishing for uranium – which could result in an essentially infinite supply of uranium. While separation efficiencies are increasing, it is still uneconomic; seawater extraction capabilities set an upper bound on the price of uranium. The United States is not in much better shape with regard to the chemical step of conversion, for which the country only has one old facility. (There is also a Canadian one.)

Similarly, only six nations can produce enough enriched uranium for their own needs, and the United States is not on that list. Enrichment is an area of extreme importance, as it is a sensitive national security stage of the fuel cycle, but the United States lacks U.S.-owned and -controlled enrichment. It was not always this way. In 1985, the United States had a huge percentage of the global uranium enrichment market outside the communist world, but the U.S. share of global uranium enrichment capacity since then has declined precipitously. While the United States has all but disappeared, Russia has rapidly risen to become the primary supplier of uranium enrichment capacity in the world, at 42%. China's market share is growing as well, now at about 10%.

The United States is the world's largest uranium importer. The first oil embargo in the 1970s was considered a crisis, given U.S. dependence on oil imports. While U.S. oil import dependence has decreased since, U.S. import dependence for uranium, uranium conversion, and uranium enrichment has shot up, but the crisis recognition is nowhere near what it was for oil. The country is about to go dark on industrial capacity to enrich uranium. There is no economic case to be made for building new U.S. capacity, as the market is morbidly oversupplied, so it has to be driven by a national security mandate. From a national security standpoint, the United States needs some amount of production of uranium and highly enriched uranium (HEU). There is a need for at least a rhetorical demand signal for the United States to be enriching uranium in the near term, as well as some financial support to avoid obliteration of what is left of U.S. institutional capacity. There is some excellent work occurring at the national labs on recovering HEU from naval fuels, which could probably supply the needs of the country for decades. A goal of building capacity for high-assay low enriched uranium (HALEU) within the next 10 years would also help sustain the current workforce and give people some reason to hope.

While the United States is lagging the world on enrichment, it is leading the world in fuel fabrication and advanced fuels (i.e., accident tolerant, or advanced technology, fuels). There are some terrific ideas on the drawing board that could have real benefits for preserving the existing fleet, advancing new build, and dealing with some fuel cycle con-

cerns. There are a number of types of fuels under consideration, but it remains unclear how and where they will be made and how a rapid path to qualification can be established; fuel testing and qualification require facilities. Some accident-tolerant fuels and new types of cladding are advancing forward to demonstrations and making headway on modeling and simulation, but the economics will determine deployment. It is not clear why utilities would deploy such fuels if they cost more.

Many advanced reactor designs require HALEU. The United States should become the first nation to develop HALEU production, getting ahead of the game and leveraging its advantages in advanced fuel production. There has to be a clear demand signal to drive installation of new enrichment capacity and the changes in infrastructure needed to shift to HALEU, but there should be a strong market signal for HALEU within a few years. HALEU needs are such that the numbers are there to justify boosting high assay capability.

WASTE

To say waste management is not a U.S. strength is putting it mildly. The United States is desperately in need of interim storage and permanent repositories. At a minimum, the country needs to start moving forward on interim storage solutions, to begin removing the logjam.

There is work to do to demonstrate a pathway to fuel disposal. There is a need to understand how used fuel behaves long-term, the implications for transportation and infrastructure, and the potential roles for recycling and pretreatment options to reduce waste volumes. Rigorous analysis will only go so far, however, as there are significant public and political obstacles to nuclear waste disposal. For instance, an attempt to develop a nuclear waste disposal facility at a geologically perfect site in Australia included studies to identify economic benefits, job gains, and why the site was geologically safe, but a citizen jury tasked with weighing all the evidence still concluded that such a facility should not be built, citing reasons of consent, trust, and safety.

Rigorous analysis will only go so far, however, as there are significant public and political obstacles to nuclear waste disposal.

In the United States, with Republican control of government and the retirement of Sen. Harry Reid, there is new momentum to move forward both the Yucca Mountain permanent waste repository and interim storage solutions. For instance, significant new legislation has passed out of the House Energy & Commerce Committee on a bipartisan basis to get Yucca back up and running, in addition to interim solutions. The NRC has requested funding in the 2018 budget for resumption of licensing proceedings for Yucca and, since the court remand, has used some carryover funds for knowledge management activities (e.g., document collection) so it is prepared if Congress does provide funding.

Burying waste is not the only option. Advanced fast reactor technologies could consume waste, converting nuclear waste into an asset and closing the fuel cycle; it could move from being *waste* (or *spent fuel*) to being *residual fuel*. This kind of advanced recycling could separate out the fission products, burn the long-lived actinides, and dispose of the fission products, thereby getting the waste down to a much more manageable 300 year half-life. Waste is one of the main things people in the public worry about, and fast reactors that burn waste that already exists can help address not just disposal problems but also public perception. Neither the public nor policymakers really understand the concept of waste-as-fuel at all; environmentalists that have long hated Yucca and nuclear waste do not understand it either. Raising awareness of how fast reactors are different and the problems they can solve needs to start now and requires leadership from the top.

The United States could take global leadership with extremely strong programs and facilities for advanced reprocessing, including fast reactors, if for no other reason than to help the many countries that will reprocess whether the United

States does or not. Some see it as ridiculous to require countries to foreswear reprocessing in order to sign a 123 agreement. The United States has to decide if it wants an open or closed fuel cycle, and it needs knowledge of reprocessing to be able to make that decision intelligently. It is important to recognize that reprocessing and recycling are red lines for many people, particularly in the non-proliferation community, and pursuing them will stir up a hornets' nest of opposition and pushback, even if fast reactors are a totally different game. That said, if the United States is not ready with its own programs to understand and comment on other countries' reprocessing processes, it will not even have a seat at the table. The United States would benefit if it had stronger international outreach and used it to leverage advanced reprocessing and fast reactors in the United States.

IMPLICATIONS OF THE LOSS OF U.S. CAPABILITY AND LEADERSHIP

A foundational principle of U.S. nuclear policy since the 1950s is that by supplying the world with the fuel and the technology, the United States can set the ground rules for the peaceful use of nuclear technologies. This was the concept behind Atoms for Peace. For decades, the United States was the alpha and the omega of nuclear technologies, but it has lost its leadership – and is on the precipice of losing it permanently. The United States has moved from global dominance in nuclear to the brink of irrelevance.

Nuclear power is increasing across the globe at the same time that American nuclear leadership is eroding. If nuclear technologies are important globally, then the United States has to care about safety and non-proliferation, which in turn requires the United States to be a nuclear leader. Nuclear energy is a global reality; the only question is whether the United States will lead or watch. The United States will have little weight in the nuclear suppliers group, where it has pushed hard for strong enrichment and reprocessing controls, if it does not lead. The United States is already starting to lose sway there.

Nuclear energy is a global reality; the only question is whether the United States will lead or watch.

Contracting with other countries to build, own, and operate reactors creates a century-long relationship. That reality is not lost on Russia or China. The question of which countries supply the fuel has major energy security and nonproliferation implications. As the United States ceases to be the favored global energy partner providing reactors and fuel, there will be long-term damage to its geostrategic influence. Unlike the old days when countries wanted their own nuclear plants, today many countries just want a solution. Russia is winning contracts all over the world because it tells countries it will mine, mill, convert, enrich, and fabricate the fuel, build, own, and operate the plants, and then take back the fuel. If the United States falls out of mining, conversion, and enrichment, then at best it can only provide bits and pieces, not end-to-end solutions. It is also hard for the United States to move ahead with takeback of foreign fuel when it does not know what to do with its own waste. The United States is getting outmatched and outplayed globally. It is already clear that the United States will not be beating China and Russia in the nuclear power game. There is a need to hunker down and preserve something in the United States.

The United States has to reestablish a supply chain impacting every aspect of the fuel cycle. The country has to take action, including attracting and retaining its human capabilities. If sustaining the people is a priority, many are about to get laid off, and losing all the experienced people will double or triple the price tag of getting back in the game later. The United States also needs to think about where the next generation of people is coming from and how new facilities and test beds will be put in place to enable people to have hands-on, not just theoretical, experience for the future. An additional concern is that engineering degrees across the board, especially at the PhD level, are being awarded to people not born in the United States, but one has to be a U.S.-born citizen to get security clearances. Combined with the supply chain issues, this represents a risk to the robustness and strength of nuclear national security programs going forward.

The United States must reassert nuclear leadership. The country invented this technology and used to dominate global markets. Now it stands behind Russia, China, France, the UK, Germany, the Netherlands, Argentina, Brazil, India, Pakistan, North Korea, and Iran in enrichment. That is a national disgrace. The loss of U.S. fuel cycle capabilities is resulting in a shrinking U.S. role in the world, which is bad for geostrategic influence, jobs, safety, and non-proliferation. Very few Americans would favor that result. The question comes down to whether the United States is in the nuclear game or not. It is not in the game if it is not building and operating plants and if it has lost its fuel cycle. It is hard to convince someone to buy U.S. nuclear products internationally if the United States cannot point back to a strong domestic market.

There is a need to come up with serious, practical solutions to get the United States back to a place of nuclear leadership – solutions that can be stuck to across parties and administrations. Restoring American leadership will require decadal investments and concrete action supported on a bipartisan basis, including perhaps establishing an Assured Nuclear Fuel Services Initiative, restoring U.S. fuel cycle capabilities, and leading in development and deployment of advanced reactors. The United States needs to take action now.

COMMUNICATING ABOUT NUCLEAR

There are a lot of challenges that nuclear power can help address in the 21st century, but it is still being viewed through a 20th century lens. Weapons, proliferation, safety, and waste follow nuclear energy around as significant baggage. Given the challenges facing the current fleet, new build, and the fuel cycle, the industry has to figure out how best to communicate about the present and future of nuclear energy.

COMMUNICATING WITH THE PUBLIC

Public acceptance of nuclear is a concern. Communicating with the public – a large, diverse audience – is a huge undertaking. The industry has to think about what the messages are, who trusted messengers are, and how best to communicate.

The literature on human thinking reveals that people have two basic mechanisms for thinking: one that is about intuition (which is quick and based on limited information) and another that involves analytical reasoning. The day-to-day world and public sentiment operate much more on the first system than on the second. Risk perception and trust heavily inform instinctive responses, and nuclear power faces hurdles with both. The public is completely misinformed about nuclear power. For instance, in some states, more people think natural gas is emission-free than nuclear power. The public also currently believes it is more dangerous to ship nuclear waste than to ship chemicals, despite the absence of any accidents; they think it is a traveling bomb. With regard to bombs, although nuclear weapons and nuclear energy should not get mixed up, they are often conflated by the public. In addition, the public's associations with nuclear power plants are Three Mile Island, Fukushima, and Chernobyl. Furthermore, it is not clear that the public trusts the industry or government with regard to nuclear power. All of these perceptions mean the industry is limping into battle and making life infinitely more complicated for itself. For example, a populace that is scared of nuclear power will not be worried about losing the existing fleet.

It is not simple to combat the public's fears of nuclear power. Education can matter. The more people know about nuclear power, the more likely they are to support it, and people who live closest to nuclear plants support nuclear the most. No one, however, is adequately taking on that challenge of educating the public, and the industry's existing messaging may even be counterproductive. For instance, while safety is a key public concern, the industry may be overdoing its external messaging to the public on safety, to the point that it makes the public worried about why the industry feels the need to stress safety all the time. One never hears airplane manufacturers talking about how safe their airplanes are; it is not their marketing strategy.

The nuclear sector is all about risk avoidance and analysis of risks and benefits – that is the way the industry constructs and operates reactors – but the risk avoidance that has infused the nuclear sector has also infused its communications, which is why there has been little shift in the conversation over the last few decades. The industry is putting forth the same messages and is evincing the same desires to engage in a big campaign to alter public

perceptions of nuclear power. The industry often wants to educate the public on the virtues of baseload power and on radiation safety, but no one cares about that, just like no one cares how solar panels work or how windmills make electricity. The challenge for the industry is to start having a different conversation and constructing a different narrative with the public focused not on risk aversion but on the things that are interesting and compelling, such as climate change, economic opportunity, and innovation. Everyone loves innovation, and it is a theme that is broader than just nuclear, encompassing electrification of transport, storage, and other developments in energy. The industry has to start communicating what is exciting about nuclear power.

Given the tight timeframe for figuring out nuclear power's path forward, there is a need for urgency in figuring out clear communications. Communications studies may need to be pursued quickly so the industry and its supporters have data on which to base their messaging and actions. This presumes, though, that there is a coherent short-term policy strategy that a communications campaign could help advance. Long-term, a way has to be found to address the way the public understands and thinks about nuclear power.

COMMUNICATING WITH POLICYMAKERS

The first step in communications is audience development, and the nuclear industry has several different potential audiences it could target with different types of messages. There has never been a more complicated, crowded, short-attention-span media environment than exists today, so the nuclear industry will have to weigh the audiences it is trying to reach and whether they will actually hear what the industry is trying to say.

Timeframes and audiences matter. It is possible to get something across the Senate floor relatively quickly without any messaging campaign, but state-by-state fights and the longer-term effort to build acceptability for a nuclear power buildout might well be different. There is therefore a key question as to whether the industry should prioritize a public education campaign or just focus on going into legislative offices with key policy asks. The industry does not have the luxury of debating these issues for another 6 or 12 months. In the near term, elite communications are a more likely route to success, as opposed to general public messaging. The industry has had some success when it has been able to deal with educated, informed officials – strategic targets with whom it can engage at a more analytical level and with whom its arguments could have resonance. On the other hand, politicians might agree in private that nuclear power has great value, but they have political agendas and are swayed by what is popular; the public showing deep ambivalence about nuclear power gives politicians room to play games.

Reaching policy-makers requires simple and clear messages. Congressional audiences, for instance, are incredibly transactional and bandwidth-constrained. They have neither the time nor the inclination to listen to long narratives; they just want to know what the people in their offices want from them. The industry should think about picking off one or two discrete policy asks and staying focused on them for years – the way that API does. A political strategy can start with small asks – proving legislation is possible and building confidence. The nuclear advocate NGOs have been pursuing this strategy the past few years, with some real successes around the advanced nuclear conversation and modernizing the NRC. There are many little levers that can be pulled to big effect.

The language used also matters in how messages are received. For example, in the minds of some policymakers and advocates, baseload is a term to be avoided, as it triggers certain associations with coal, leads to arguments that solar plus storage (perhaps plus demand response) are equivalent to a baseload resource, and raises questions about whether the term even means anything in a world with times when there is so much renewable power on the system that there is no need for 24/7 resources. For these audiences, terms such as *firm, on-demand,* and *flexible base* may be better. Other policymakers, however, are still solidly in a baseload mindset, including in the Administration. Similarly, *intermittent* may be a term to avoid with some audiences, with *variable* or *weather-dependent* preferred instead.

Different strategies and messages will be needed to leverage and sustain the existing fleet and the current fuel cycle than for new build or advanced reactors and SMRs. To address issues related to the existing fleet, the industry has a great story to tell about capacity factors, safety, jobs, tax bases, and more. The existing fleet is a good thing that policymakers should not want to lose. Although it is hard for the engineers who dominate the nuclear industry, communicating values and stories about people is often far more impactful than communicating science-based rationales. What turned the day for the natural gas industry were the people they could talk about benefitting from wells; that helped them get over the top with elected officials. The nuclear industry has seen a few similar examples, such as efforts to prevent plant closures that would have big impacts on people. The impacts on people and jobs go beyond nuclear power as well, to other existing U.S. nuclear technology capabilities such as deep space exploration, industrial applications, medical isotopes, and more. This broader scope of stories can create images in people's minds about nuclear other than just a cooling tower and Homer Simpson at the controls.

There is potential to get bipartisan support for nuclear power.

Although there is not as good a story in this country with regard to new build – particularly when the few being built are over-schedule and over-budget – policymakers' excitement around advanced reactors could be used to help pull along the existing fleet and some new build. It is challenging to convince policymakers to bail out a dying industry, but advanced nuclear is the next iteration of current technologies. The future can help pull the present along. There is even an argument to be made that the industry should put all its eggs in the advanced nuclear basket in terms of messaging and should back-fit its other needs into the advanced messaging. A unifying theme could be innovation and jobs, which could then encompass the existing fleet, new reactors, and the fuel cycle. Particularly for the Administration, the jobs messaging should keep their attention. It is worth remembering, though, that while advanced reactors have exciting potential, none of them are ready, which means the messages would be for something that cannot be bought or seen today.

There is potential to get bipartisan support for nuclear power. On the right, Republicans love nuclear power and have for decades. Sometimes they cannot tell you why they do – it is technology invented by the government, only deployed with government help, and so forth – but they do. Even Republicans who dispute the need to take any action to address climate change still show strong willingness to support nuclear power (and carbon capture and storage). On the left, lots of people who used to oppose nuclear power are coming around, recognizing that having nuclear power on the table may be important for dealing with climate change. There are only a handful of Senate Democrats who would be hard "no" votes on supporting nuclear power. There is willingness on the left to cut deals, as illustrated by the fact that the states where actions were taken to support existing nuclear plants were mostly Democratic states motivated at least in part by climate change.

MOVING FORWARD

The industry probably has less than five years to figure out how to solve the challenges facing nuclear power, and some argue it only has 18 months or less. The industry is on the brink and has already atrophied. Nuclear advocates therefore have to figure out the policy asks, coalition partners, and other material steps that are essential to the industry's near-term survival, as well as what is needed in the medium and long term.

DETERMINING THE PRIORITY ASKS

President Trump gave a speech in June 2017 at the US Department of Energy announcing a review to revive the nuclear energy sector – with few details beyond that. No Administration comes into office ready to deal with nuclear power, as no one campaigns on nuclear power, and this Administration is no different; it does not yet have fully formed positions. Some White House staff hold views that are helpful, whereas others want more of a Heritage Foundation blueprint that could work against some of the nuclear industry's goals. White House staff are looking for policy guidance, which represents an opportunity for the industry and its supporters to articulate a handful of things that the staff can encourage the President to get behind.

A challenge is to separate out the various issues facing the industry. The urgent issues of the existing fleet are separate from promotion of advanced reactors, which are separate from issues about international exports and about fuel cycles. At the same time, the issues are linked, and the sector is not big enough to only have discrete pieces of it advocating for discrete policies. There cannot be 40 different rationales offered for the future of nuclear; there is a need to hone down the key arguments for decision-makers who do not live and breathe nuclear power issues on a daily basis. Focusing on core elements – such as climate change, national security, jobs, international competitiveness and leadership, innovation, and resilience and fuel diversity – could combine to make a compelling argument, with different elements exciting some policymakers more than others. Many of these elements point in the same direction with regard to nuclear energy policy; people can agree on what to do even if they do not agree on why.

Beyond the overarching rationales, the specific policy asks have to be crafted and honed to ensure they will actually make a difference and could actually happen. For instance, while a real or imputed price on carbon is preferred by many as a means of supporting nuclear power, it is unlikely to be well-received by the current Administration and Congressional leadership. Other asks may not be material to the immediate crises facing nuclear plants, although they may be needed in the short term to facilitate the longer term. It is also important to acknowledge that the industry has asked for support before, gotten it, and yet still encountered hurdles and failures in getting Summer and Vogtle built. Materiality, feasibility, and timeliness are important criteria as the industry decides what its policy asks are that will actually move the needle. The goals have to involve preserving and sustaining the existing fleet (including getting the markets right and bringing costs down), promoting innovation and getting new technologies built, and thriving in global competition.

In the short term, one focus could be getting a national priority statement on nuclear power out of the White House. There is a need for a clear vision at the highest level, such as Atoms for Peace and Prosperity, supported by simple, clear, compelling arguments. Such a high-level mission statement, which could be part of a State of the Union speech, could include an assertion about restoring U.S. nuclear leadership in order to be able to: provide clean, reliable, and secure energy for civilian and national needs; strengthen the country's ability to defend its freedoms; advance the country's prosperity; and fight the spread of nuclear weapons. It could lay out some key, overarching policy goals, such as being a global nuclear power in all dimensions (across the range of nuclear technologies that benefit humanity), sustaining the existing fleet of nuclear reactors, innovating and building new generations of advanced reactors and fuels, and providing the fuel needed for civilian and national security needs and disposing of it safely. These kinds of high-level objectives are broad enough to be inclusive and to resonate with people but specific enough to provide direction. The objectives could theoretically go even broader, encompassing a larger platform around clean energy, deep decarbonization, and the future of America – areas that can give a sense of a national and global imperative – but the current Administration would not embrace the climate angle.

Other short-term policy priorities could include actions to protect the existing fleet (whether at the federal or state level), loan guarantees, extension and reform of the 45J tax credit, reform of 123 agreements, creation of a HALEU reserve and the capability to enrich uranium up to 20%, and regulatory reform to facilitate the licensing of advanced reactor designs. Some of these are already included in bills moving in Congress, though little has made it across the finish line. The loan guarantees are a good example of an existing policy tool that the Administration should maximize to support the nuclear industry. There are actions that DOE can take to make them more flexible, such as streamlining the process and fixing the rules that say a company cannot combine a federal loan guarantee and a federal PPA because of budget scoring. At the same time, there needs to be a united front arguing for the continued existence and availability of the loan guarantee program, which Congress is planning to gut, as well as resistance to the Administration's desire to focus federal research only on early-stage R&D.
These types of priorities could see action in 2017 and could be short-term wins that could prevent the legs from being kicked out from underneath longer-term hopes.

The importance of nuclear is not matched by federal funding.

Medium-term priorities could include encouraging FERC to reform markets to value resilience and fuel diversity, encouraging FERC to more broadly reform wholesale markets to address price formation concerns, creating multi-year public-private partnership funding commitments, completing licensing and starting construction on a permanent waste repository by 2025, and beginning to accept fuel at interim storage facilities by 2022. In addition, with regard to international funding, the Administration wants to change the terms of the Green Climate Fund so that it is not solely directed at renewables; the Administration has been advocating "clean coal", but the industry should try to get nuclear power (including perhaps advanced nuclear) included too.

Longer-term asks could include creating federal PPAs for new advanced nuclear generators (though that may not be the best route for first-of-a-kind plants), conducting a study on potential options for re-utilizing used fuel, and revising radiation standards (which currently are not based on science). A national carbon price would also be really helpful; to address climate change, there is a need to adequately provide compensation for zero-carbon generation.

Many of these priorities will require significant funds; nuclear energy will not be saved and advanced on the cheap. Within the federal government, there is broad recognition of the importance of commercial nuclear energy and growing recognition of the role nuclear energy plays from a national security and global non-proliferation perspective – but the importance of nuclear is not matched by federal funding for nuclear. Government resources and investments in nuclear are far too small for the problems the country faces. The very real urgency has to be not only acknowledged but also financed. Despite the current politics, the industry should not assume hostility to a pitch for more money for nuclear power, but the industry has to make the case for it and carefully frame a dollar amount. For instance, funding levels in recent disaster response bills have shot up quickly, and nuclear power performed well throughout the disasters; out of the crises may come opportunities for nuclear.

COALITION BUILDING WITH CLIMATE ADVOCATES AND OTHERS

Particularly because it is so difficult to envision popular support for nuclear changing much, the industry cannot forsake coalition building if it wants to achieve its policy goals. The industry has to get outside of its echo chamber and think about bringing others into the conversation. Key constituencies to build support with include environmental NGOs, labor groups, other industries (e.g., local chambers of commerce), academics, conservative organizations, the international development community, national security and non-proliferation groups, the mainstream media, the entertainment industry, professional athletes, and others that could be more appealing messengers to the public. There are already ecosystems around concerns such as clean air, climate change, U.S. technological leadership, and national security, and they have to be educated on how nuclear can help their agendas and on why they should have a nuclear element in their messaging to the public, policymakers, and the media. The industry also needs to focus on building public trust, including outreach to minority communities; even though the nuclear industry is older, whiter, and more conservative than where the country is headed, there is no reason for nuclear power not to embrace the environmental justice challenge.

There are opportunities for the industry to build relationships with climate advocates. Climate pressures push in favor of nuclear energy. Looking at the deep decarbonization literature, there is strong agreement that a diversified mix that includes nuclear offers the best chance of affordably achieving deep decarbonization. Although climate change is now as divisive in the United States as abortion, the industry should not shy away from making the climate argument and emphasizing nuclear power's zero-carbon attributes in building coalitions and public outreach, though it may be advisable to leave climate out of messaging to the Administration and Congressional Republicans.

The industry will face some serious headwinds, however, in building relationships with much of the environmental community. For one thing, the idea of achieving climate goals with 100% renewable energy is very appealing and has many adherents in the environmental community (and among the public), even though a number of experts argue that it is neither a serious proposal nor a viable roadmap. In addition, many environmental NGOs do not trust the nuclear industry. Their perception is that the nuclear industry never talks about climate change and is never vocal in supporting climate actions, the Clean Power Plan, or even methane regulations. Whether true or not, the perception affects the relationship between the industry and a potential ally. Although there have been a few environmental interests making the case in states to protect the existing fleet, environmental groups generally have not come to the industry's aid; most of the environmental community that does show up at state proceedings is the strong anti-nuclear crowd. (It is not clear that state policymakers are aware there is a pro-nuclear part of the environmental community.) Even organizations that appear willing to support nuclear power privately – recognizing it as needed for deep decarbonization – will not do so publicly, for fear of losing funding; philanthropies call the tune for their grantees, and philanthropies are generally far more on the anti-nuclear side than their grantees are. There are also some board members of these organizations who have been anti-nuclear for decades. For the most part, the connection between the environmental community and the nuclear community is pathetically tenuous. There is lots of work to do to bolster environmental support for nuclear power.

COORDINATION OF NUCLEAR ADVOCATES

There is an enormous amount of work going on to support nuclear power, including a fairly coordinated effort over the past couple of years with some of the more engaged NGOs and funders in the nuclear space. There is also starting to be increased NGO coordination with the industry. There is more work to do, however, to elevate coordination to a higher level in order to make progress in a short window. If nuclear advocates cannot manage to get on the same page and speak with one voice (which does not have to imply total agreement on everything), then they will be unable to convey clear asks to the White House and Congress – and they risk getting nothing. There is a need for an integrated strategy that empowers people to act in a more coordinated, strategic, and effective manner and that

nurtures potentially supportive allies to generate a broader base of support. The strategy should be multi-stakeholder, including NGOs, government, industry, national labs, utilities, and more. There could be key areas of focus – including zero-carbon / climate, geopolitics and security (including non-proliferation), international competitiveness, and resilience, reliability, and fuel diversity – with key issues, policies, and technologies under each. Such a strategy could create a larger platform for networking people across issue areas, although adding groups and voices increases the coordination challenge.

Over the next 18 months or less, there will be a need to figure out an organizational structure for this strategy – an umbrella across the issue areas that is somewhere between centralized and disaggregated. This structure will need transparency in order to build trust, humility in order to recognize where groups can and cannot be helpful, and a basis in reality. The umbrella structure has to be able to absorb information, watch the entire dashboard, and make sure that action is happening where needed across issue areas – not just reactively but also proactively as part of an overarching strategy.

A core challenge is that there is a huge range of issues to address with very limited resources. Outside entities trying to support the industry (e.g., NGOs) have far too few resources, and nuclear is barely on the philanthropic map. For instance, there is a great deal of grant-making on climate change, but a very small fraction of that goes to support nuclear power. The groups working on nuclear are in a scrum for crumbs. Many also will not take industry money. Many industry players emphasize charitable giving by their employees, and it would be good to find a way for employees to be able to contribute personal dollars to these kinds of NGO efforts.

Coordination is needed in the states as well to provide outside information and expertise. For instance, the nuclear working group within the National Association of Regulatory Utility Commissioners tends not to have outside groups that come in to inform and provide perspectives, and there has only been informal outreach to the National Conference of State Legislatures as well. There are significant opportunities at the state level for different voices and types of expertise to be heard in debates about nuclear power, but the engaged NGO nuclear advocates have limited bandwidth to keep track of regulatory proceedings in 50 states. It would take them very little time to provide assistance in state policy discussions (e.g., letters to regulators), but those in the states need to communicate with the NGOs and convey the need for assistance.

The enhanced coordination of nuclear advocates could help them to start getting more base hits. The country has to start doing stuff on nuclear and showing some success – such as getting some SMRs built, starting to build uranium enrichment capacity, licensing the next advanced reactor, or opening interim storage facilities. There is a need to get things done, and done in a reasonable time frame, to start showing momentum.

APPENDICES: AGENDA

Opening Session	**Introduction**	**David Monsma**, Executive Director, Energy and Environment Program, The Aspen Institute
	Welcome	**Dan Poneman**, President and CEO, Centrus Energy Corp. **Joseph Dominguez**, Executive Vice President, Exelon Corporation

SESSION I: **The Current Situation: Setting the Stage**

Moderator: Dan Poneman

Discussants:
Mark Peters, Laboratory Director, Idaho National Laboratory
Shane Johnson, Deputy Assistant Secretary for Nuclear Technology Demonstration and Deployment, US Department of Energy
Rich Powell, Executive Director, ClearPath Foundation
Joseph Hezir, Principal, Energy Futures Initiative

SESSION II: **The Case for Nuclear: Communications and Analyzing Risks and Benefits**

Moderator: Josh Freed, Vice President, Clean Energy, Third Way

Discussants:
Jeff Navin, Partner, Boundary Stone Partners
Armond Cohen, Executive Director, Clean Air Task Force
Jeffrey Binder, Associate Laboratory Director, Energy and Global Security, Argonne National Laboratory
Rachel Slaybaugh, Assistant Professor, Department of Nuclear Engineering, UC Berkeley

SESSION III: **Regulation: A discussion with the Chairman of the NRC**

Moderator: Dan Poneman

Discussants:
Kristine Svinicki, Chairman, Nuclear Regulatory Commission

SESSION IV: **Saving the Fleet: Issues for the Current**

Moderator: Joseph Dominguez

Discussants:
Richard Mroz, President, New Jersey Board of Public Utilities
John Kotek, Vice President, Policy and Public Affairs, Nuclear Energy Institute
Kathleen Barrón, Senior Vice President, Exelon Corporation

SESSION V: **Restoring America's Fuel Cycle**

Moderator: Pete Lyons, Former Assistant Secretary for Nuclear Energy, US Department of Energy

Discussants:
Dan Poneman, President and CEO, Centrus Energy Corp.
David Klaus, Former Deputy Under Secretary for Management and Performance, US Department of Energy
Alan Icenhour, Associate Laboratory Director, Nuclear Science and Engineering, Oak Ridge National Laboratory

SESSION VI: **From Drawing Board to Deployment: The Next Generation**

Moderator: Joseph Dominguez

Discussants:
John Herter, Senior Consultant, Energy Options Network
Jon Ball, Executive Vice President, Nuclear Plant Projects, GE Hitachi
John Hopkins, Chairman and CEO, NuScale Power
Christina Back, Vice President, Nuclear Technologies and Materials, General Atomics

SESSION VII: **The Road Ahead: From Talk to Action**

Moderators: Dan Poneman and **Joseph Dominguez**

PARTICIPANTS

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Jon Ball, Executive Vice President, Nuclear Plant Projects, GE Hitachi Nuclear Energy

Kathleen Barrón, Senior Vice President, Competitive Market Policy, Exelon Corporation

Fred Beach, Assistant Director for Policy Studies, Energy Institute, The University of Texas at Austin

Jeffrey Binder, Associate Laboratory Director, Energy and Global Security, Argonne National Laboratory

Caroline Cochran, Co-Founder and COO, Oklo Inc.

Armond Cohen, Executive Director, Clean Air Task Force

Liz Dalton, Global Lead, Energy and Climate, One Concern

Jacob DeWitte, Co-Founder and CEO, Oklo Inc.

Joseph Dominguez, Executive Vice President, Government and Regulatory Affairs and Public Policy, Exelon Corporation (*Co-Chair*)

Ron Faibish, Senior Director of Business Development, General Atomics

Jay Faison, Founder and CEO, ClearPath Foundation

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Kristine Svinicki, Chairman, Nuclear Regulatory Commission

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RECOMMENDATIONS

Below is a non-exhaustive list of specific recommendations. Please note that these are not recommendations that were agreed upon by participants, but merely discussed as options.

Wholesale Market Reform	**The President** should encourage FERC to enact energy and capacity price formation reforms to avoid discrimination against flexible, dependable generators such as nuclear power plants.
National priority statement on nuclear energy	**The White House** should include a national statement in the State of the Union and other venues on the priority of maintaining US nuclear dominance.
Federal PPAs for new advanced nuclear generators	**DOD and DOE** should create a nuclear power purchase program for at least 6 SMRs and advanced reactors by 2020.
Recycling and reprocessing technology development	**DOE and NRC** should develop a US policy to re-utilize used fuel, including in fast-spectrum burner reactors.
Nuclear Production Tax Credit	**The President** should work actively with the Congress to pass extension and reform of the 45J advanced nuclear production tax credit.
Supporting state programs for existing reactors	FERC should respect state programs that support nuclear energy, like the recently enacted in Illinois program.
123 Agreement Reform	**The President** should instruct the **DOE/NNSA/DO**S to aggressively and quickly expand the number of Section 123 Agreements to enhance exports.
Interim Used Nuclear Fuel Storage	Begin accepting fuel at 2 interim storage facilities by 2022.
Permanent Used Nuclear Fuel Storage	Complete licensing and commence construction of permanent repository by 2025.
Advanced nuclear fuel capacity (light water, non-light water, enrichment)	Create an HALEU reserve and the US owned ability to provide commercial uranium enrichment up to 20%.
Regulatory Reform	Facilitate the licensing of Advanced Reactor designs in 3 years or less through the NRC.
Tax Reform	Congress should provide a level playing field for investments in new and existing nuclear power plants.