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THE ROLE OF U.S. RESEARCH AND DEVELOPMENT POLICY IN NUCLEAR POWER

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ABSTRACT

The U.S. civil nuclear sector faces a number of challenges that threaten grid reliability and climate mitigation goals.[1] Though current U.S. reactor designs improve confidence in the predictability of construction schedules and costs, the United States is unlikely to see a substantial expansion of its nuclear fleet in the near future. The biggest current obstacles are cheap shale gas and continued mandates and subsidies for other forms of generation, particularly renewables. State and federal agencies, including the Environmental Protection Agency, should treat nuclear power like any other non-emitting source. Furthermore, the federal government should refocus its nuclear research and development programs. Of particular value to improving the competitiveness of nuclear power would be advances that reduce operation and maintenance costs for the existing fleet and that improve the thermal efficiency and fuel burn-up of future reactors, thus reducing waste streams and significantly increasing revenue streams for owners and operators. A new fast test reactor that allows testing of advanced concepts should be built as soon as possible, to achieve these strategically important objectives.

INTRODUCTION

The vitality of the U.S. civil nuclear sector is incredibly important to national interests. Washington's ability to shape global safety standards and the nonproliferation regime depends largely on U.S. leadership in commercial nuclear technology. If the United States becomes a marginal provider of nuclear goods and services, countries seeking to develop nuclear energy programs are likely to turn more and more to major foreign suppliers. Because of the political stature of the United States, new entrants continue to seek Washington's blessing of their programs, but foreign governments will be less pressured over time to agree to tough U.S. nonproliferation conditions, particularly as U.S. content in nuclear technology declines. From a defense perspective, the U.S. Navy benefits substantially from a robust domestic civil nuclear program and the supply chain it provides, as well as the post-military jobs in the sector that ease recruitment efforts. Without it, Washington would need to build capacity solely for national

1. This report in large part reflects discussions at the Sept. 17, 2014 Capitol Hill "Forum on the Economics of Civil Nuclear and the Role of Research and Development." Roundtable participants included senior officials from national laboratories, universities, the federal government, industry and other stakeholders. The views expressed in this report are those of the author.

security purposes and increase pay incentives for recruits, resulting in greater demands on the federal budget.

Unfortunately, the U.S. civil nuclear sector is in decline. The United States has fallen behind in reactor construction and has lost the capability to manufacture large reactor-pressure vessels. Of the roughly 70 new reactors under development around the world, only five projects are located in regulated U.S. markets, while China, India and Russia account for sixty percent of the total.[2] U.S. market share of nuclear-related exports is also tumbling, as American firms face intense competition from state-backed foreign enterprises that benefit substantially from favorable financing, subsidies, turnkey services and fuel take-back options.[3] In addition, the U.S. private sector is disadvantaged by a nonproliferation policy that does not always reflect the current state of the global market for nuclear technology.[4]

The existing fleet of reactors, as well as other baseload capacity,[5] also faces major challenges, particularly in deregulated power markets,[6] due to cheap shale gas and flaws and distortions in energy and capacity markets. Absent policy changes and a strategic research and development investment plan at the federal and state levels, U.S. nuclear-generating capacity could fall to about 80 gigawatts of electrical output by 2030, down from roughly 100 GWe at the beginning of 2013.[7]

Such a decline in zero-emissions nuclear power would prevent a number of U.S. states from achieving greenhouse gas reduction goals proposed by the Environmental Protection Agency (EPA); in 2012, U.S. nuclear plants avoided 570 million metric tons of carbon dioxide emissions.[8] The early departure of nuclear units from the grid would also threaten reliability. In January 2014, for instance, the extreme cold weather exposed major vulnerabilities in the security and reliability of our nation's electric power supply. The nuclear fleet had significantly lower forced outage rates than any other energy source, with a very high average capacity factor of 95 percent playing a crucial role in preventing widespread outages.

2. World Nuclear Association, "Nuclear Power in China," January 2015. http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/China--Nuclear-Power/

3. U.S. Government Accountability Office, "Nuclear Commerce: Government Wide Strategy Could Help Increase Commercial Benefits from U.S. Nuclear Cooperation Agreements with Other Countries," Report to the U.S. House Committee on Foreign Affairs, November 2010. http://www.gao.gov/assets/320/311924.pdf

4. George David Banks, "A Rational Approach to U.S. Civil Nuclear Power," R Street Institute, May 23, 2014. http://www.rstreet.org/wp-content/uploads/2014/05/RSTREET23.pdf

5. Baseload power is the average amount of power used at any given time. Baseload plants – such as coal and nuclear – can run continuously, in contrast to peaking plants, which usually operate during high demand (e.g. hot summer days during the week).

6. In merchant or deregulated markets, generators respond to market demand and sell their electricity at the going market price. In contrast, generators in regulated markets receive a price that is determined by state regulatory authorities, which allows them to recover the cost of their investment, plus an authorized return. Accordingly, ratepayers in regulated markets shoulder the financial risks, while deregulated power generators and their investors bear the risks in those markets.

7. Michael Wallace and George David Banks, "Restoring U.S. Leadership in Nuclear Energy: A National Security Imperative," Center for Strategic & International Studies, p. xvi, June 2013. http://csis.org/files/publication/130614_RestoringUSLeadership-NuclearEnergy_WEB.pdf

8. Nuclear Energy Institute, "Environment: Emissions Prevented," http://www.nei.org/Knowledge-Center/Nuclear-Statistics/Environment-Emissions-Prevented. Accessed Feb. 14, 2015.

CAPACITY MARKETS AND THE EXISTING FLEET

About half of the U.S. nuclear fleet is located in deregulated markets. Cheap shale gas, which sets electricity prices in most deregulated markets, has driven the price of power down substantially. Moreover, prices have been depressed by the sluggish economy and lower demand for electricity, as well as government-mandated energy efficiency programs. Deregulated markets, all of which have renewable portfolio standards (RPS), also suffer from subsidized generation and federal incentives that inject new generation into markets, whether or not it's needed. At the same time, operation and maintenance costs are growing, in part thanks to post-Fukushima regulations, as well as increased capital expenditures at power plants as they prepare for relicensing or for uprates.

These market conditions and distortions negatively affect nuclear fleet operations. The early retirement of two small reactors (Kewaunee and Vermont Yankee) was blamed on cheap shale gas, subsidized renewables and a poor market structure that does not fully value baseload power. In energy markets, subsidies for other forms of generation – particularly for renewables, as well as guaranteed revenue streams for combined-cycle natural gas – suppress prices. The expansion of subsidized wind, in particular, has substantially increased pressure on nuclear plants across deregulated markets. According to a 2012 study from the Organization for Economic Cooperation and Development,[9] a 10 percent penetration of wind energy produces a 4 percent load loss and a 24 percent drop in profitability for nuclear operators. Those numbers worsen substantially when wind generates 30 percent of the grid's power, leading to a 20 percent load loss and a reduction of 55 percent in profitability.

In addition, capacity markets do not sufficiently value baseload, including nuclear and coal units. In fact, less reliable resources, such as demand response and intermittent renewables, are valued as much as baseload power in some markets. Compensating capacity but not reliability drives down electricity prices and pushes out capital intensive units that cannot survive with artificially low prices. As a result, the grid is becoming increasingly dependent on less reliable generation, as baseload power exits the market.

9. Nuclear Energy Agency, "Nuclear Energy & Renewables: Systems Effects in Low-Carbon Electricity Systems," OECD, December 2012. http://www.oecd-nea.org/ndd/reports/2012/system-effects-exec-sum.pdf.

In Illinois, for example, the continued operation of several nuclear reactors is in serious doubt, putting at risk the state's ability to comply with expected federal greenhouse gas regulations. The state has seen a massive deployment and continued injection of wind power in electricity markets that are already struggling with excess generation. In last year's capacity auction in PJM,[10] 7,000 megawatts of nuclear capacity did not clear that auction for the first time, including four units at Byron and Quad Cities. Because revenues from energy markets have dropped substantially and the cost of regulatory compliance has increased, those reactors required significant capacity payments, over and beyond what the market was willing to pay, to cover operational costs. Such problems could be addressed if Washington and state governments pursued a technology-neutral approach to emissions reductions, rather than favoring intermittent renewables over baseload nuclear power.

Complicating matters is the intersection of policies from different levels of government and the role of regional transmission organizations and independent system operators.[11] Most energy market distortions flow from state policies (e.g., renewable-portfolio standards and energy-efficiency mandates), though some federal policies (e.g., the wind production tax credit) also have major negative effects on existing nuclear units. Grid operators in deregulated markets, under the oversight of the Federal Energy Regulatory Commission, shape capacity markets, often in ways that fail to provide adequate compensation to nuclear power. There remain significant risks related to regulators and market operators failing to assign value to reliability, affordability and diversity. Decisions based solely on current market conditions – without consideration of diversity – likely would result in the monopolization of investment dollars by natural gas, which would leave the U.S. grid vulnerable to supply and demand shocks impacting one feedstock. This is not a viable energy security strategy for our nation.

THE EPA'S CLIMATE PROPOSAL

For some time, many nuclear proponents have hoped that a cap on carbon via legislation or regulation would help solve the nuclear industry's woes or spur a renaissance. Unquestionably, the United States cannot meet goals requiring deep greenhouse gas emissions cuts without maintaining and expanding its fleet of nuclear reactors. Roughly 60 percent of the nation's emission-free generation last year came from the nuclear sector. When considering a social cost of carbon of $42 a ton, the U.S. nuclear sector provides up to $25 billion in annual value, for which it currently receives no compensation. A technology-neutral approach to emissions reductions would greatly benefit nuclear power in energy markets and help the United States meet its environmental objectives.

However, the EPA's current proposal to regulate carbon dioxide emissions from existing plants (also commonly referred to as the Clean Power Plan or 111d proposal) fails to give proper credit to nuclear power.[12] For example, the agency considers 6 percent of the nation's existing nuclear capacity at risk of premature retirement, threatening the compliance pathway for a number of states. In an attempt to create an incentive for states to maintain those reactors, the EPA has proposed adding 6 percent of the 2012 nuclear megawatt-hours to the denominator when calculating a state's intensity target. However, there is no logical basis to assume that 6 percent of the nuclear generation in every state with nuclear capacity is at risk of early retirement. For example, far more than 6 percent of nuclear generation in Illinois is threatened; the number is actually closer to 45 percent.[13] To better account for intensity, the EPA should examine the health of each reactor and make a reasoned determination as to the potential impact of early retirement on a state's attainment of carbon targets.

Moreover, the Clean Power Plan would actually help lock in market distortions, such as renewable portfolio standards. These distortions increase pressure on a number of nuclear reactors, as RPS targets ramp up over time and reduce substantially the odds of new builds in those states. That would undermine the actual intent of the proposal – to reduce greenhouse gas emissions through increased deployment of clean-energy generation – because wind and solar generation requires back-up power to produce electricity when the wind is not blowing or the sun is not shining. Unfortunately, mandates and subsidies for other forms of generation, especially renewables, are more likely than not to continue for the foreseeable future because of entrenched special interests.

In this context, the success of ongoing construction of new Westinghouse AP1000 reactors in Georgia and South Carolina is incredibly important to build confidence amongst the investment community, which has mostly moved past Fukushima-related concerns, that schedules and budgets can

10. A regional transmission organization that stretches from Illinois to Delaware is responsible for moving electricity across the interstate market. It coordinates, controls and monitors the grid.

11. An Independent System Operator coordinates, controls and monitors the operation of the grid within a state or an area including multiple states, while an RTO typically covers a larger geographical area.

12. Under EPA's proposal, states that have already invested in new nuclear are also penalized. Nuclear plants under construction in Georgia, South Carolina and Tennessee are treated as though they are already operating at 90 percent capacity. The EPA adds the output of those future plants to the denominator, despite the fact that these plants are not complete and not operating. In addition, adding potential output from these plants to the denominator in the rate-setting formula drives the state's intensity target down. Although states would be able to receive credit for new nuclear plants – by counting their output in their compliance calculations – that credit is effectively nullified by including that output in the rate-setting formula.

13. Jeffrey Tomich, "Exelon Says Nuclear 'At Risk' Designation is Little Help," E&E Publishing, Sept. 25, 2014. http://www.midwestenergynews.com/2014/09/25/exelon-says-nuclear-at-risk-designation-is-little-help/

be reasonably predictable at a relatively low risk. Engineering and construction improvements reflected in the AP1000 should help the financing of new power plants, especially in regulated markets. Two of its key design attributes that create greater certainty in construction are passive safety systems, which reduce the amount of required equipment and instrumentation, and the use of steel concrete composite structures that can be prefabricated off-site. In addition, the U.S. licensing framework also provides some advantages. When an operator seeks a combined license for a new plant that references an existing design certification, its review will focus on site-specific matters that are novel to the application, with more than 90 percent of the issues already pre-approved.

Nonetheless, any success in regulated U.S. markets is unlikely to be replicated in deregulated areas of the country, particularly given flaws in the energy and capacity markets. For the foreseeable future, building large reactors like the AP1000 in deregulated markets is highly improbable. There is some hope that commercialization of small modular reactors will attract the interest of merchant utilities, despite lost efficiency resulting from scaling down the reactor (i.e., increased cost-per-megawatt). SMRs would allow utilities to add incremental capacity, using the first unit to leverage and finance the next, and avoid betting the farm on one big plant. SMRs also fit better with the smaller load profile of deregulated markets. However, they are unlikely to be competitive on price with other sources, especially natural gas. They also produce more nuclear waste per kilowatt-hour than their large-scale counterparts. The current investment in SMRs does not advance technology, but represents a wager on the future competitiveness of light-water technology.

CRUCIAL ROLE OF RESEARCH AND DEVELOPMENT

Given budgetary constraints and a growing political consensus against mandates and subsidies, it is unlikely the domestic nuclear industry would benefit in the near term from federal programs like production tax credits and enhanced loan guarantees. However, there is strong bipartisan support for basic early-stage research, demonstration and nuclear-energy science. This support could be focused on accelerating the development, deployment and commercialization of advanced reactors that are more efficient and have higher fuel burn-up, thus making them more competitive with shale gas and subsidized generation. [14] Accordingly, policymakers should view the nation's research and development program for nuclear energy as playing an indispensable role in reversing the decline of the sector and recapturing U.S. leadership.

The role of the federal government in research and development is fairly simple: focus on what industry cannot and will not do on its own. That generally means investing in high-risk, high-reward R&D that focuses on the fundamental underlying science, materials and nuclear cross sections and processes. It is very difficult for private investors to contemplate research programs with very long timelines for realizing returns. Researching new materials presents an even greater challenge, due to uncertainty about which industries will be most affected by any success, let alone whether a given discovery will even be relevant to nuclear energy or a particular choice in nuclear technology.

More importantly, government should advance the private sector's progress and not suppress innovation. R&D policy should increase private industry choices, but not so much that it invades the private sector's space. Once government proves the technical viability of a technology – for example, with a test reactor and/or demonstration project – the market should determine if it can sink or swim on its own. Too much government intervention can result in poor choices about deployment that can be difficult to abandon. Even in the case of China, which can invest enormous labor to accelerate construction, some reactor designs are intrinsically difficult to build on a reasonable schedule and budget (e.g., the European Pressurized Reactor).[15][16]

There are multiple nuclear research areas that are important to the commercial sector,[17] but budget constraints require prioritization. Currently, nuclear energy research policy has problems with scale and with focus, resulting in a budget that is spread too thinly. This approach is unlikely to result in the commercialization of technology in the appropriate timeframes. At the same time, R&D policy should maintain sufficient flexibility to take advantage of "ripeness" – that is, areas where the fundamental science and the capabilities have evolved such that additional investment by the federal government could open up possibilities for private-sector engagement and leadership.

Generally, the research community, concentrated in the national labs and universities, is not driven by profit motives. It thus will choose complicated and interesting problems, not necessarily those that matter most to industry. As a technology gets closer to the marketplace, industry is better positioned to identify which problems research needs to address.

14. New nuclear technologies will drive higher performance levels. The evolution of technology typically follows an S curve – just as computing, transportation and communications do -- with one breakthrough resulting in the next discovery.

15. Jussi Rosendahl and Geert De Clercq, "Finnish Nuclear Plant Delayed Again as Areva, TVO Bicker," Reuters, Feb. 28, 2014. http://uk.reuters.com/article/2014/02/28/tvo-olkiluoto-idUKL6N0LX3XQ20140228

16. Peter Kirby, "Europe's New Nuclear Experience Casts a Shadow Over Hinkley," *The Guardian*, March 25, 2014. http://www.theguardian.com/environment/2014/mar/25/europes-new-nuclear-experience-casts-a-shadow-over-hinkley.

17. Forum participants focused mainly on R&D policies that advance high-temperature materials required to increase efficiency, fuel-cycle matters and steps that could be taken to improve the cost competitiveness of light water reactors

Unfortunately, the U.S. private sector largely has been left out of advanced research policy, significantly diminishing the likelihood of commercialization.

REFOCUSING R&D POLICY

Federal policymakers have attempted to construct frameworks that encourage stronger R&D relations with the private sector. Under the Energy Policy Act of 2005, Congress established cost-sharing requirements for research, development, demonstration and commercial application activities, all as a means to measure private industry interest in a given technology.[18] Under cost share, the private sector is required to cover at least 20 percent of the total cost of a research and development project. If industry is not willing to invest its share, the government automatically assumes the technology is not ripe to pursue.

Cost share, however, sometimes serves as a disincentive to industry involvement, thus obstructing innovation. Because developing nuclear technology takes a relatively long time, it is often difficult for a company to justify such a high-risk investment without much prospect to recover capital.[19] When industry actually accepts cost share, it sometimes views the government portion as a subsidy for what it would do anyway. Generally, that means incremental technology improvements. The combination of cost-share constraints and a lack of federal R&D funding drives many U.S. firms to partner with foreign entities, who are willing to explore advanced R&D without requiring a cost share that hits the bottom line.

R&D cost share needs to be reformed to increase the private sector's engagement in high-risk, high-reward research and development projects.[20] Selection criteria and the source selection process should be designed to identify the most promising ideas. The responsibility for funding high-quality proposals must be based on a rigorous process, free of bias and dogma within the community of interest. This is feasible only given proper government leadership and guidance and competent monitoring.

The United States maintains significant leadership in light water reactor technology, particularly in the commercial deployment of passive safety systems for reactors and steel/concrete composite structures. Some continued investment in light water technologies is practical and helpful to maintaining the sector,[21] but the federal government should focus a growing portion of its R&D efforts toward helping the United States transition from light water to advanced designs that are more competitive, safer and more proliferation-resistant. (In late October 2014, about a month after the forum, the Department of Energy announced it would provide millions in cost-share arrangements to help companies address design, construction and operation issues related to more efficient, next-generation nuclear reactors.)[22]

As with mature technologies, light water reactors have topped out in performance, with additional improvements becoming more expensive and with related costs increasingly difficult to pass down to the consumer. In recent years, natural gas and coal plants have seen substantial gains in efficiency. Ultra-supercritical coal plants have a thermal efficiency of about 45 percent, a significant improvement over sub-critical plants,[23] while the natural gas fleet in California achieved substantial gains of more than 17 percent in thermal efficiency between 2001 and 2010.[24] By contrast, light water efficiency has remained flat for decades, at 33 percent.[25] At the same time, operations and maintenance costs have increased, adding to the competitiveness gap between nuclear and other generation sources.

Increased thermal efficiency[26] is absolutely critical to efforts to improve the competitiveness of nuclear power. Unfortunately, LWR technology can't achieve the efficiencies needed, because of design and coolant constraints dictated by physics. Current materials (i.e., metals) used inside a light water reactor lose strength at about 700 degrees Centigrade. To reach higher temperatures that improve reactor performance and efficiency, the United States will need to move toward advanced designs and new materials, focusing specifically on ceramics (e.g., silicon carbide composite, uranium carbide, uranium nitride). A more intense federal research program on ceramics is needed to accelerate breakthroughs for materials that can reach higher temperatures.

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18. As an example, the Next Generation Nuclear Plant program had substantial funding from a technology standpoint, but could not secure appropriate cost share from industry. Therefore, it was determined there was not enough industry interest to proceed, so the U.S. Department of Energy pulled back NGNP to an R&D program.

19. One participant in the forum pointed out that, if a company chooses to accept the 20 percent condition, it is likely that management would have pursued the investment regardless of the level of government support.

20. This report does not address cost-share approaches for non-R&D programs. For example, the Department of Energy's licensing technical support for SMRs is a cost-share approach with industry to facilitate deployment by moving through the NRC licensing process.

21. The existing fleet clearly has benefited from R&D successes that allow reactor licenses to be extended from 40 to 60 years, and potentially to 80 years. Given the cost of building new reactors, this breakthrough has helped maintain the domestic supply chain and investments in human capital, particularly in deregulated markets where utilities simply would replace nuclear units with other forms of power generation like natural gas.

22. Tim DeVaney, "DOE invests in more efficient nuclear power plants," The Hill, Oct. 31, 2014. http://thehill.com/regulation/222466-doe-invests-in-more-efficient-nuclear-power-plants.

23. John Kemp, "Cleaning up coal," Reuters, July 10, 2014. http://www.reuters.com/article/2014/07/10/us-coal-technology-kemp-idUSKBN0FF0E720140710

24. Michael Nyberg, "Thermal efficiency of gas-fired generation in California," California Energy Commission, August 2011. http://www.energy.ca.gov/2011publications/CEC-200-2011-008/CEC-200-2011-008.pdf

25. For every three units of thermal energy generated by a reactor, only one unit is distributed to the grid. The remainder is wasted.

26. Thermal efficiency is the ratio between electricity and heat produced.

Gains in efficiency would dramatically change revenue streams for owners and operators of nuclear plants. For example, an improvement in thermal efficiency by one percentage point is worth roughly $500 million over the course of 30 years. Moving from today's average efficiency rate to 53 percent would result in an additional $10 billion to investors, dramatically changing the price point of electricity. Moreover, more efficient reactors produce less waste, further reducing costs. (One forum participant argued that a 60 percent efficiency improvement would reduce waste stream by 80 percent and improve burn-up by a factor of three relative to current light water reactors.) [27]

The United States should align its research policy as much as possible with the nation's educational efforts. Given that commercialization of advanced technology remains some years away, much of the current generation of nuclear experts will not be involved in the development of the next set of plants. Federal funds are needed to educate the next generation of scientists – not only for university R&D, but for scholarships, fellowships and young faculty awards.

THE NEED FOR AN ADVANCED TEST REACTOR

One of the greatest challenges facing humanity this century will be to provide universal access to affordable and reliable energy, a goal that is indispensable to poverty eradication efforts, economic prosperity and political stability.[28] Advanced reactors could play a vital role in helping achieve this goal. Based on proven global reserves of uranium and total annual energy consumption, the world would have 2,000 years of energy if an advanced reactor could extract all of the energy from those resources, not to mention the potential uranium reserves in seawater and as-yet undiscovered material resources.

To achieve the breakthroughs necessary to develop, deploy and commercialize advanced reactors, the United States needs to build a test reactor that can reach very high temperatures – roughly 1,000 degrees Centigrade and high-neutron flux – in order to support high-performance testing of component technologies and materials. This country's two current older test reactors cannot reach those higher temperatures, forcing U.S. companies to conduct related research overseas, including in Russia. This dependence undoubtedly creates vulnerabilities, particularly given the current political relationship between Washington and Moscow.

A test reactor should be versatile to serve the needs and interests of a wide range of stakeholders, capable of researching a number of advanced concepts and thereby creating competition within the broader community. Testing a variety of concepts would decrease risk to industry, giving more predictability to financial models.[29] It also must be a fast reactor[30] that can capture fast neutrons and set up hot loops to elevate the environment to the required temperatures. A fast reactor also could be designed to allow light water research to continue.[31]

A more flexible advanced design that allows for major component replacement would spread risk between operators and vendors, which could help produce breakthroughs in materials and temperature regimes.

Potentially, the Nuclear Regulatory Commission could actually license an advanced reactor through a test reactor, providing a significant boost to efforts to accelerate deployment and commercialization. There is no question that the commission should devote more resources to working on advanced licensing concepts, but Congress would need to make the NRC's budget more flexible to achieve this goal.[32]

According to unpublished industry estimates, the cost of a fast test reactor could approach $2 billion, posing a potential budget challenge.[33] However, this must be weighed against the United States losing its leadership role in nuclear energy and the attrition of our nuclear workforce. To reduce the cost to government, it is possible to create public-private partnerships where there is infrastructure support (e.g., siting a reactor at a national lab and/or an actual user facility open to a broad community). International partnerships also present another opportunity to spread the cost of a test reactor. Argonne National Laboratory, for example, is already working with South Korea on fast reactor technology, providing expertise to help support the design effort. Through this partnership, Argonne is introducing U.S. design concepts and also building expertise.

27. General Atomics, "Energy Multiplier Module: EM2." http://www.ga.com/websites/ga/docs/em2/pdf/FactSheet_QuickFactsEM2.pdf Accessed Feb. 13, 2015.

28. Access to energy also is needed for clean water and resilient health systems. Globally, more than 700 million people lack access to clean drinking water, with 1,400 daily childhood fatalities due to water-borne illnesses.

29. General Atomics uses a discounted cash flow analysis model that depends on various types of performance criteria for component technologies. The company examines those technologies that have the greatest impact on net present value, which is a measure of the financial viability of the targeted technology. General Atomics then focuses on opportunities to reduce risk by understanding new performance well enough that predictions can be made with more confidence.

30. A fast reactor has a fission chain reaction sustained by fast neutrons. Compared to a thermal reactor, it uses fuel that is relatively rich in fissile material. A thermal reactor uses slow neutrons. Most nuclear power plants in the world are thermal reactors.

31. Neutrons can be slowed down but cannot be sped up.

32. The NRC's funding is recovered through a fee basis that is back-charged to those who use the commission's services, which is primarily the power industry. The NRC, by law, is required to recover 90 percent of its appropriation through those fees.

33. This estimate was provided by a few forum participants.

CONCLUSION

The U.S. nuclear sector is a national asset worthy of preservation to meet domestic economic, energy security and environmental goals. It also is crucial to U.S. national interests because of its inherent link to the nonproliferation agenda and importance to the U.S. Navy, including its supply chain and recruitment efforts. From a global perspective, zero-emissions nuclear technology, exported by the United States, can help fuel a new wave of industrialization in large parts of the developing world where it is appropriate (e.g., India, South Africa, and Vietnam), offsetting the need of poorer, less stable countries to exploit fossil fuels, particularly coal, for electricity access.

To help protect the existing fleet, Washington and state governments need to take a technology-neutral approach to emissions reductions. Nuclear power should be treated the same as other non-emitting sources. Regulators and grid operators should pursue initiatives that provide adequate compensation for the positive attributes of nuclear power, including on-site fuel, diversity of supply and reliability. The premature shutdown of reactors because of market distortions and flaws would threaten grid reliability and attainment of environmental and climate policy objectives. Moreover, as long as government favors renewables over nuclear, the private sector will be less willing to invest in the future of nuclear power.

In any case, nuclear power needs to become vastly more efficient, which will improve its competitiveness with shale gas and subsidized generation. Unlike natural gas and coal plants, which have seen substantial gains in efficiency, light water efficiency has remained flat for decades at 33 percent. Unfortunately, current light water reactor technology will never be able to achieve the needed efficiency levels, because of inherent design and coolant constraints. The United States should therefore shift more of its research dollars into advanced nuclear concepts and new materials that will enable higher temperatures and more efficient reactors with higher fuel burn-up, which in turn will produce greater revenue streams and significantly reduced waste.

Regarding research and development, the federal government should focus on what industry cannot do and will not do on its own – generally high-risk, high-reward research. Government should advance the private sector's progress and not suppress innovation. As part of this effort, Washington should explore reforms to current cost share requirements for research and development that actually reduce innovation and, in some cases, subsidize what industry would do anyway. In addition, given the long period of time needed to commercialize nuclear technologies, the federal government should align as much as possible its research and development program with education priorities, including the need to train a new generation of nuclear engineers and experts.

It is absolutely crucial that United States invest in a new fast test reactor. The nation's two current test reactors, both of which are planned to be shut down within the decade, cannot test advanced concepts, which forces U.S. industry to conduct research overseas, including in Russia. The U.S. fast test reactor should be versatile and capable of testing a number of different concepts, a capability that would help win broader support across the nuclear energy community. The fast test reactor also should be designed to advance light water research, which is important because the existing fleet is composed of LWRs. Because of the expense of a fast test reactor, the United States should explore public-private arrangements or partnerships with foreign governments to share costs. It is time for the United States to take a bold step and to once again lead the world in innovation.

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From 2004 to 2006, he served as the State Department's point person on climate change and energy diplomacy at the U.S. Mission to the EU in Brussels, Belgium, where he received a Superior Honor Award for promoting U.S. diplomatic objectives. He was also a decorated CIA economic analyst and served as legislative fellow to Rep. Howard Berman, D-Calif.

A native southeast Missourian, Dave received his bachelor's and a master's in economics from University of Missouri at St. Louis, and also has a law degree from George Mason University.