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MEMORANDUM FOR: John Podesta
FROM: John Deutch and Richard Lester
SUBJECT: Outlook for U.S. Nuclear Power
DATE: August 13, 2014

We have given consideration to the following two questions: (1) what is the likely attrition in the U.S. nuclear fleet in the near and longer term? and (2) what measures might the U.S. government take to reverse this trend? The views expressed are our own but we believe they are in line with informed and realistic industry experts. Since we understand you are interested in these questions, we are sharing our answers with you.

In sum, the near and longer term outlook for U.S. nuclear power is poor for reasons summarized below. There is little the USG can do to influence decisively the outcome over the next decade because this will mainly be determined by the economic competitiveness of nuclear units in many markets under prevailing state regulatory provisions. We make a number of suggestions for actions the USG might take soon to create an enabling environment for nuclear generation over the longer term.

I. What is the outlook?

1. Anticipated shutdowns to 2020. Four nuclear reactors have been closed since 2012 and Vermont Yankee will also close by the end of 2014, for a total of 4.2 GWe capacity. At least 10 more units are at risk of closing during the next decade, including 4 in Illinois, 4 in New York, 1 in Ohio, and 1 in New Jersey, with a combined capacity of 9 GWe. Many factors influence closure decisions including anticipated electricity demand, misalignment of base load capacity, market prices and dispatch rules, projected growth in nuclear O&M and capital costs, and perhaps more stringent safety requirements in response to Fukushima, so there could be more or fewer closings than the 10 noted here.
2. Anticipated additions to 2020. Five nuclear units are under construction (2 at the Vogtle station in Georgia, two at the Virgil Summer station in South Carolina, and one at Watts Bar, TN). These reactors will add about 6 GWe of capacity by the end of the decade. No one expects any additional new plants to enter service before 2020. So the nuclear capacity in 2020 will be about the same as it is today, i.e., 95-100 GWe. The EIA in its AEO 2014 reference case projects 98 GWe.
3. Retirements beyond 2020. The EIA AEO 2014 reference case assumes no additional retirements during the period 2020 to 2040. This is unrealistic

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because it assumes that the 50 GWe of capacity reaching 60 years of age between 2030 and 2040 will all be granted a further 20-year operating life extension, and that O&M costs will remain flat. But these aging reactors may well continue to experience rising O&M costs (these have recently been increasing at 3 – 4 %/year), which would likely mean a drop in nuclear generation and the high capacity factors that nuclear units have enjoyed. Also, it is unlikely that all eligible reactors will receive (or even apply for) permission to operate out to 80 years of life.

The EIA has an accelerated nuclear retirement case that projects no operating license extensions beyond 60 years and hence 36 GWe retirements (about 1/3 of the existing fleet) between 2029 and 2040. Even this case could prove optimistic. The main point here is that even with resolution of the near term problems caused by dispatch rules and unrecognized value of capacity, there remains the looming prospect of post 2020 retirements that should be addressed now.

4. Commercial prospects for new LWR construction. Estimates of the overnight cost to build a new nuclear reactor in the U.S. (including owner's costs) are about \$5000/kW, in 2014 dollars. On the same basis, a natural gas combined cycle plant would cost around \$1100/kW. This translates to about 7.5¢/kW-h for nuclear compared to about 4¢/kW-h for natural gas generation at \$4/MCF of natural gas. The credit for carbon free electricity generation required to bridge this gap would be very large and there are many other opportunities in the economy to reduce carbon emissions at lower cost. Even assuming successful completion of the Vogtle and Summer reactors, new LWR construction starts are unlikely if the gas price remains at its current low level, as anticipated for at least a decade.

Some believe costs are much lower overseas. We have not done a recent review of costs in China, Finland, India, and Korea but our impression is that under a common set of assumptions, the costs of LWR are rising everywhere.

5. What about the new Small Modular Technology (SMR)? The DOE is supporting the development of SMRs with the objective of mass producing many small reactors at low cost and ganging them together as needed to meet demand. It is an audacious idea: instead of pursuing ever larger units to achieve lower cost, mass produce many smaller units in a factory setting and achieve low cost through production scale economies and 'learning'. This may succeed but the following needs to be kept in mind: development, licensing, and demonstration of a new reactor type is both expensive and takes time; over \$10 billion and 10 years. There is no plan for how these costs will be shared between the government and the private sector. There is also little technical evidence to support the basic hypothesis, so it is imprudent to adopt SMRs as the "solution" to the impending post-2030 nuclear plant retirement problem today.
6. Other technology opportunities. It is important for the U.S. to remain engaged in nuclear energy even if the future is clouded. There are many opportunities

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where U.S. interests and capabilities could lay the groundwork for a Nuclear 2.0 future. These suggestions are in the next section.

II. What might the USG do?

For the near term we suggest two actions (#1 and #2 below). For the longer term we offer six actions (#3 to #8) to establish a technological and governance basis for domestic and global nuclear expansion in the long term.

1. Strengthen FERC's determination to assure that Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) resolve the uncertainty on capacity value and a dispatch priorities so that nuclear (and coal) plants can more reliably estimate their future revenues and costs.
2. Establish that policy and regulations will value existing and new nuclear generation on the same basis as other carbon-free electricity sources. This will give utilities and investors confidence that nuclear energy is an accepted part of the energy future of the U.S.
3. Convene an international nuclear safety evaluation designed to establish requirements for new reactors capable of achieving expected safety levels an order of magnitude beyond the current level.
4. Continue to support the U.S. nonproliferation policy. The key elements are: (a) to ensure that the U.S. is a reliable supplier, (b) to encourage international mechanisms to provide enrichment services and stockpiles of low-enriched fuel, and (c) to avoid reprocessing of commercial spent fuel.
5. Establish the NRC as the global leader in licensing innovative nuclear technologies. The key elements are: (a) to create a separate NRC unit dedicated to regulatory development and licensing of innovative nuclear technologies; (b) encourage engagement of this unit with international nuclear development consortia; (c) accelerate the creation of a risk-based regulatory pathway for advanced technologies; (d) establish a clear roadmap for licensing approval of advanced technologies, with well-defined milestones.
6. Upgrade and internationalize DOE's nuclear RD&D programs. Priority areas are: (a) hybrid nuclear energy storage systems suitable for grid with high levels of intermittent generation, wind and solar, (b) uranium recovery from sea water, (c) advanced waster disposal technologies such as deep bore holes, (d) offer INEL and other DOE national laboratories as sites that domestic and international industry can use for development, testing, and demonstration of advanced nuclear technologies, (e) support materials R&D and testing that validate reactor lifetime extension beyond 60 years.
7. Attention to nuclear waste storage and disposal is important to establish public confidence in nuclear energy. The administration should move to implement the recommendations of the *Blue Ribbon Commission on America's Nuclear Future*,

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chaired by Lee Hamilton and Brent Scowcroft that lays out a comprehensive and practical approach to nuclear waste management. An especially important step to signal progress on this issue is authorizing Away From Reactor (AFR) storage for spent commercial nuclear fuel.

8. What should be avoided? At the present time expanding or extending the nuclear loan guarantees is unpromising. Also, the SMR initiative is not at a stage that justifies a costly “crash” program and cannot be relied upon to offer a safe and economical source of electricity in the post 2025 period.

We have not shared this memorandum with Ernie or others. If you would find it useful to expand these views into a more complete paper we will do so in response to your invitation. Of course, we will be pleased to learn any reactions you may have to these ideas.

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