SEAB Subcommittee on Small Modular Reactors (SMR)

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In his April 3, 2012, Memorandum to Secretary of Energy Advisory Board (SEAB) Chairman William Perry, Secretary of Energy Steven Chu charged:

"The broad purpose of the SEAB subcommittee on SMRs is to advise the Secretary on ways to advance this technology to achieve a global leadership role in civil nuclear technology for the United States, and ways for DOE to accelerate that role."

In the context of the Subcommittee's deliberations, it is important to note that the Department of Energy Office of Nuclear Energy issued a Funding Announcement Opportunity (FOA) on March 22, 2012, for a Small Modular Reactor Licensing Technical Support Program; a government-industry cost share program for the expeditious design certification and licensing of up to two SMRs. The subcommittee had no engagement with this FOA process and, because DOE's evaluation of proposals was underway at the time of our work, we were not able to interact with any of the potential bidders. All the information that the Subcommittee received was based upon publically available sources. At the time of this writing, the Department of Energy (DOE) had not yet announced the awardees for this procurement.

Specifically, Secretary Chu charged, "Looking beyond the current DOE program authorized by Congress and begun by the FOA, this SEAB Subcommittee will:

(1) Identify areas in which standards for safety, security and nonproliferation should be developed for SMRs to enhance U.S. leadership in civil nuclear energy, and
(2) Identify challenges, uncertainties and risks to commercialization and provide advice on policies and other approaches that may be appropriate to manage these risks and accelerate deployment in support of national goals."

In carrying out these tasks, the Subcommittee had briefings from the DOE Nuclear Energy Office and as part of an open meeting, the Nuclear Regulatory Commission (NRC), the Natural Resource Defense Council, The Union of Concerned Scientists, the NNSA Office of Defense Nonproliferation, the University of Chicago team which is analyzing SMR economics for the DOE, and Senator Pete Domenici, who has led a study of nuclear futures for the Bipartisan Policy Center. We also heard from other interested parties and the public at large at this open meeting. The Subcommittee subsequently heard from DOE briefers on advanced SMR concepts, foreign SMR activities, and the Staff Director of the Senate Energy and Natural Resources Committee. To provide an industry and utility SMR perspective on potential U.S. government activities beyond the DOE SMR FOA, the Nuclear Energy Institute (NEI) organized a meeting with a wide range of potential vendors and utilities, attended by Subcommittee members Dr. Andrew Kadak and Dr. William Madia**.** Dr. Kadak summarized the results of the

NEI meeting for the Subcommittee. Similarly, to obtain an SMR perspective from the DOE sites and local communities, the Energy Community Alliance (ECA) organized a meeting attended by many of the DOE communities. Dr. Madia attended this meeting and summarized the ECA meeting for the Subcommittee.

We believe that if SMRs are to play an important role in achieving U.S. civil nuclear leadership, the U.S must develop a domestic robust SMR industry that will produce, in time, numerous SMRs that are both cost competitive with electricity generation alternatives and meet stringent U.S. regulatory standards. Such an SMR industry could provide the United States with important, perhaps critical, contributions to the U.S. national goals in clean energy, reducing carbon emissions, non-proliferation, energy security, and international industrial competitiveness. But developing that SMR industry will be both costly and financially risky and the U.S. government will likely have to play a significant financial role in that industrial development beyond the current licensing cost-share program.

The U.S. government has a wide range of tools (e.g. loan guarantees, "feed-in" tariffs, further cost sharing, etc.) to provide assistance, but there is significant uncertainty as to the feasibility, effectiveness, and cost of the application of these tools. Our recommendation is for the Secretary of Energy to analyze whether such an investment is warranted after the Small Modular Reactor Licensing Technical Support Program is underway, and to update this analysis as the NRC process continues and more information becomes available.

To review briefly, the SMRs that the subcommittee discussed are much smaller (<300 MW(e)) than most conventional commercial reactors, and if they are to meet the congressional requirement in funding the Small Modular Reactor Licensing Technical Support Program for "expeditious deployment," they would most likely be based upon current nuclear light water reactors using low enriched uranium fuels. The SMRs would be built in a factory as a complete steam supply module and then transported by rail or truck to a generating site where they would be connected to conventional steam turbines and electric generating equipment. Factory fabrication opens the prospect of reducing costs by working in a controlled environment with a dedicated workforce that enables improvement through "learning" and improved quality. The number of modules at each reactor site could be sized to meet the anticipated demand. Continued advances in safety and security are in principle likely to result from simplicity in design, robustness to seismic events, much greater coolant to thermal power ratios, below ground emplacement, and other features. The smaller size and modular construction represent a promising match with the financial structure of privately owned utilities that represent a large fraction of the U.S. electricity supply, and lastly it would appear that the industrial base to support an SMR industry is domestically available.

The Subcommittee findings are as follows:

Task 1: Identify areas in which standards for safety, security, and nonproliferation should be developed for SMRs to enhance U.S. leadership in civil nuclear energy.

1) While SMRs present some new safety issues (e.g. controlling and securing multiple reactors, defining appropriate emergency planning zones), the NRC appears well prepared to apply their processes to design, certify, and license those pressurized light water SMRs that use standard low enriched uranium fuel. Because U.S. NRC licensing is generally considered to represent the "gold standard" of international safety and security regulation, a successful U.S. SMR certification and licensing program will enhance U.S. leadership in civil nuclear energy, providing both safe and secure designs for SMRs and a regulatory model for others.

2) A light water, low-enriched uranium fueled reactor operating in an open fuel cycle is considered to be a "safeguardable" reactor configuration, and therefore those SMRs that meet these criteria would appear to meet the international non-proliferation standards. Specifics await detailed analysis of the SMRs under consideration.

Task 2: Identify challenges, uncertainties and risks to commercialization and provide advice on policies and other approaches that may be appropriate to manage these risks and accelerate deployment in support of national goals.

If SMRs are to support national goals (low cost clean energy, non-proliferation, energy security, and industrial competitiveness), they must be deployed in significant numbers, which in turn implies the creation of a robust, domestic factory-based SMR industry. Beyond design certification and licensing, a primary risk for commercialization of SMR is: Can the cost of factory built and field assembled SMR electricity generating plants be driven down sufficiently by learning, without compromising safety and security, to the point that SMRs become cost competitive with alternatives and desirable to U.S. generating companies? The main domestic alternative at this stage would be natural gas fueled power plants given the anticipated wide scale deployment of hydraulic fracturing. Also unknown is whether power produced by SMRs would be less costly than power produced by the next generation of large nuclear plants. Promoters of SMRs expect that the economies of scale that go with large conventional reactors will be compensated by the lower cost of factory-built models produced in larger numbers and, therefore, that the power produced by SMRs will have comparable costs per kilowatt and per kilowatt-hour. The companies and industrial consortia that are proposing these devices do have considerable experience with construction of large, high-tech devices, but there is a potential problem. Designs are not complete and the NRC has not yet certified any designs so it is possible that requirements imposed by the NRC will affect costs.

It is also expected that there will be a learning curve that reduces the costs that go with first builds of any large device. The shape of the learning curve is itself uncertain though some of the proponents have been through this sort of thing before. While published estimates of SMR initial production (and operation) costs are in the "ball park," and the learning factor in somewhat analogous industries (in particular the industrial base supporting the U.S. nuclear Navy) is promising, both are at best rough estimates. However, first of a kind costs in U.S. practice will likely make the early units considerably more expensive than alternative sources of power. If the U.S. is to create a potential SMR market for US vendors, it will need to do something to help out with such costs. The decision whether to launch such a program should

be undertaken after NRC requirements affecting costs and commercial viability are decided and the uncertainties surrounding the ability of a mature SMR industry to compete in the market are more clearly resolved. The assessment should include an evaluation of the costs and benefits of support for SMRs in the context of other possible sources of power and the contribution each can make to national goals.

If a decision is made to proceed, the government "investment" should be at a scale that promises success; half measures will be likely insufficient and hence will prove to be wasteful. U.S. government has panoply of direct and indirect tools available to support the development of an SMR industry. These range from the government funding SMR demonstration plants, perhaps on U.S. government sites (the DOE is a particularly large user of electricity) to a variety of financial incentives, e.g. continued cost sharing with selected SMR vendors beyond design certification, loan guarantees, production tax credits or feed-in tariffs for those utilities generators that are early users of SMR power purchase contracts, and other possible techniques. In terms of international deployment of SMRs, U.S. export control policies need to be benchmarked against other nations who seek to sell SMRs. Analyzing the potential cost and effectiveness of these tools – individually or in combination – was beyond the capability of the subcommittee's effort, but an assessment of the effectiveness of these tools should be undertaken as part of the SMR evaluation we recommend.

While the risks of creating a viable U.S. industry are significant, it is also useful to consider the risk to national goals if the government does not support an SMR program beyond the current Small Modular Reactor Licensing Technical Support Program. Without some form of continued U.S. support, it is likely that the SMR program will be considerably delayed in time or even fail to proceed to commercialization. The U.S. has currently around 100 GW of nuclear powered electricity capacity, producing some 800 TWh of emission free electricity, or around 20% of the U.S. electricity supply, and 30% of the world's nuclear generated electricity. Assuming that reactor licenses will terminate at 60 years, by the year 2035 70% of the current U.S. reactors will be retired, and by 2050 all of the current U.S. reactors will be retired. If these retirements can be replaced by a combination of large conventional nuclear power plants and cost-effective SMRs, it would make for a more reliable power grid with more widely distributed generation, would support the goals for clean generation and reduced carbon emissions, and help to preserve the U.S. influence in non-proliferation by being a player, not just an observer.

Conclusions:

1) A U.S. industry building and deploying to U.S. electricity suppliers light water, low enriched uranium fueled SMRs holds considerable promise of establishing the U.S. as a global leader of civil nuclear technology, directly supporting many of the nation's high priority clean energy, national security and economic competitive goals.

2) Establishing such an SMR industry is a long-term endeavor and would likely require continued sustained U.S. government support going beyond the current Small Modular Reactor Licensing Technical Support Program through the first-of-a-kind cost-recovery phase.

3) There are currently many unknowns that would influence a satisfactory result. The Subcommittee recommends that the Secretary of Energy charter an integrated government SMR strategy after there is more clarity concerning the many uncertainties surrounding the commercialization of SMRS. This strategy should be revised and updated from time to time.