Written Testimony

of

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Chairman Feinstein, Ranking Member Alexander, and Members of the Committee:

My name is Chris Mowry and I am the President of Babcock & Wilcox Nuclear Energy, a business unit of The Babcock & Wilcox Company (B&W), and Chairman of Generation mPower, LLC, which is a majority-owned subsidiary of B&W. I would ask that my entire statement and supplemental information be entered into the Committee record. My prepared remarks will be a summary of this statement.

I appreciate this opportunity to present testimony today on the promise of small modular reactors (SMRs) and describe our innovative technology - the B&W mPower™ reactor. I will focus my testimony on the technical, safety and economic attributes of SMRs and am happy to respond to any questions.

B&W has more than 50 years of continuous nuclear engineering and manufacturing experience. Today we provide customers with nuclear manufacturing and nuclear-related services from more than 17 facilities across North America. These locations are engaged in activities from manufacturing major components for government and commercial nuclear power plants, to operating the Nation's nuclear energy laboratories, to fabricating fuel for the High Flux Isotope Reactor at Oak Ridge National Laboratory and the University of Missouri's research reactor, both of which provide critical research and material testing services.

B&W operates significant nuclear manufacturing facilities in Indiana, Ohio, Virginia and Tennessee, as well as Ontario, Canada. We are the only American manufacturer accredited and capable of producing large N-stamped components for commercial nuclear power plants. We have delivered more than 1,100 Nuclear Steam Supply System (NSSS) components and pressure vessels, including approximately 300 nuclear steam generators worldwide. And, we employ (both directly and through joint venture companies) approximately 12,000 U.S. nuclear professionals. As such, we have significant experience and expertise to validate the technical, safety, and economic value of SMRs.

Inherent Safety of SMRs: Robust Defense-in-Depth

Current and next-generation U.S. large reactor designs operate at a remarkable level of safety, making the United States the global leader in nuclear safety and security. While the current fleet is considered safe, in the wake of the devastating earthquake and tsunami in Japan, and the resultant emergency at the Fukushima—Daiichi nuclear plant, the nuclear community—including Congress, the Nuclear Regulatory Commission (NRC), the industry and the general public—is evaluating what additional layers of safety are appropriate to mitigate these types of challenges. Our efforts to work together to learn from Japan's experiences will help make the current U.S. fleet and new nuclear technologies even safer than they are today.

The B&W mPower SMR offers significant safety enhancements to NRC safety goals through the use of an inherently safer plant architecture and significant defense-in-depth safety systems. This enhanced safety performance is achieved through the following design features:

- An integral nuclear steam supply system with no large reactor penetrations in the primary cooling circuit,

- a small core, low power density and large water inventory that provide a large buffer against short-term challenges to core cooling,
- deeply embedded underground containment, which effectively isolates all emergency cooling water sources and safety systems from natural disasters and external threats,
- safety systems powered by gravity and natural circulation with no dependence on external AC power, and
- underground spent fuel storage with large cooling water volume, located within the auxiliary containment structure created by the underground reactor service building.

These innovations transcend the design of the reactor at Fukushima-Daiichi. This design results in a reactor planned to be 2-3 orders of magnitude safer than the current NRC requirement or EPRI Utility Requirements Document (URD) safety benchmark, based on core damage frequency (up to 10^{-8} vs. 10^{-5} NRC requirement or 10^{-6} EPRI URD goal). In the unlikely occurrence of an event, the B&W mPower reactor design also creates an extended period of time before outside assistance is required to maintain safe shutdown of the plant. Specifically, our B&W mPower reactor design creates a 14-day “safe haven” before any intervention is required to maintain reactor core cooling through the ultimate reactor cooling water source (ultimate heat sink), and provides more than 30 days of inherent protection before the spent fuel pool could experience any exposure of spent fuel due to loss of cooling water volume through boiling. Furthermore, our design requires zero emergency operator action for the first 72 hours after an emergency reactor shutdown, which is best in class for all advanced light water reactor designs, large or small. This allows the operators to focus on long-term mitigation of events rather than immediate emergency actions.

The SMR industry is in a unique position to efficiently incorporate both design and regulatory lessons learned from Fukushima into our designs. We have an ongoing, extensive effort to evaluate the B&W mPower SMR design in the context of what we are learning about the events at Fukushima. B&W’s evaluation is confirming that the safety performance of our SMR design is extremely robust when confronted by a Fukushima-type event.

Integral Design & Robust Safety Margins

The B&W mPower reactor’s integral design means that the entire reactor and steam supply system are incorporated into one vessel, rather than multiple vessels connected by large piping. This integral design, with no penetrations in the primary cooling circuit of the reactor vessel below the core, eliminates the possibility of the worst-case design basis accident occurring, an accident in which a loss of cooling water to the reactor is caused by a break in the reactor system piping. In addition, the B&W mPower reactor’s small core combined with low density of power and large inventory of reactor coolant, results in operating and safety margins significantly more robust than those required by the NRC.

Deeply Embedded Underground Containment & Reactor Building

The integral B&W mPower reactor module is isolated from external events in a steel containment structure, which is itself enclosed within a massive reinforced concrete reactor building that is fully embedded underground. This water-tight underground reactor building contains all emergency cooling water sources (including the refueling water storage tank and ultimate heat sink), isolates all safety equipment from natural disasters, and creates an auxiliary containment for the protected underground spent fuel pool. In a Fukushima-type event, this means that all systems and cooling water needed to protect the reactor core for an extended period of time are well isolated from the effects of natural disasters. This underground configuration also offers inherent protection against external man-made threats such as aircraft and projectiles.

Inherent Safety Systems
The B&W mPower reactor incorporates the most advanced inherent safety system architecture. This means that no AC power, either onsite or offsite, is required to power any safety systems. No pumps are required to inject cooling water to the core. Instead, the emergency core cooling system is powered by gravity—natural circulation removes decay heat and a gravity-drained storage tank supplies make-up water to cool the reactor core. This ultimate heat sink provides up to 14 days of cooling without the need for external intervention. Unlike at Fukushima, no diesel generators are required to provide power for any of these safety systems to perform their intended functions. However, in keeping with our defense-in-depth philosophy, two back-up diesel generators are provided anyway, in seismically qualified structures, for further protection. In addition, a three-day battery supports all plant monitoring and control for 72 hours without reliance on AC power. After 72 hours, which is the NRC's current regulatory requirement for passive safety designs, auxiliary power units inside the underground reactor building recharge the battery system, again without reliance on external power sources. Finally, passive hydrogen recombiners prevent the build-up of hydrogen, from either the reactor core or the spent fuel pool, in the containment and reactor building. Most importantly, all of the inherent safety systems, including the ultimate reactor cooling water source (ultimate heat sink), batteries, battery recharging system, and hydrogen recombiners are housed inside the protected underground reactor building, isolated from natural disasters.

Robustly Protected Spent Fuel Pool
Our design includes a fully protected spent fuel pool located within the auxiliary containment structure created by the underground reactor service building, at the lowest point of the structure. Consistent with the design philosophy of an advanced, inherently safe reactor, the B&W mPower SMR provides protection for spent fuel similar to that which is provided for the fuel in the reactor core itself. As shown at Fukushima, protection of spent fuel is most critical in the first few years after it is removed from the reactor core. Therefore, the spent fuel pool's auxiliary containment structure, inside the underground reactor building, has a similar level of robustness as that protecting the reactor vessel. This ensures an enhanced level of protection for spent fuel recently removed from the core. In addition, it is designed with a large heat sink to ensure more than 30 days of fuel cooling without the need for external intervention, before the loss of water inventory sufficient to uncover fuel could occur—which may have been experienced at Fukushima within one week of the accident.

These design safety features are summarized in Figure 1. The underground reactor building is illustrated in Figure 2.

Design Considerations for "Fukushima-Type" Events

generation *mPower*

Events and Threats	B&W mPower Reactor Design Features
Earthquakes and Floods	• **Seismic attenuation**: Deeply embedded reactor building dissipates energy, limits motion • **"Water-tight"**: Separated, waterproof reactor compartments address unexpected events
Loss of Offsite Power	• **Passively safe**: AC power not required for design basis safety functions • **Defense-in-depth**: 2 back-up diesel generators for grid-independent AC power
Station Blackout	• **3-day batteries**: Safety-grade batteries support all accident mitigation for 72 hours • **Auxiliary Power Units**: Protected inside reactor building for recharging batteries • **Long-duration "station keeping"**: 7+ day battery supply for plant monitoring/control
Emergency Core Cooling	• **Gravity, not pumps**: Natural circulation decay heat removal; water source in containment • **Robust margins**: Low core power density and small core limit energy release • **No operator action required**: for 72 hours to mitigate consequences of an accident
Containment Integrity and Ultimate Heat Sink	• **Passive hydrogen recombiners**: Prevention of explosions without need for power supply • **Internal cooling source**: Ultimate heat sink inside underground shielded reactor building • **Extended performance window**: Up to 14 days without need for external intervention
Spent Fuel Pool Integrity and Cooling	• **Protected structure**: Underground, inside auxiliary containment • **Large heat sink**: 30+ days before boiling and uncovering of fuel with 20 years of spent fuel

Multi-layer defense … mitigates extreme beyond-design basis challenges

Figure 1

B&W mPower™ Reactor

Figure 2

Some groups, including the Union of Concerned Scientists (UCS), have raised concerns related to the safety of SMRs. I agree that we have an obligation to reexamine nuclear safety based on the events at Fukushima. However, the UCS statements regarding SMR safety are unfounded and inaccurate. In particular, I would like to address concerns the UCS has raised related to an alleged "weakening" of NRC regulation to support SMRs, and locating multiple reactors on one site.

No "Weakening" of NRC Regulation

In testimony provided to the Senate Energy & Natural Resources Committee earlier this year, the UCS made several statements implying that SMRs require softer regulatory standards to be viable, stating that we as the SMR industry are "pressuring the Nuclear Regulatory Commission to weaken certain regulatory requirements for SMRs." This is a mischaracterization. The B&W mPower reactor design, will meet or exceed all of the NRC's current safety and security requirements. While the way in which an SMR design intends to meet or implement an NRC requirement may differ from large reactor designs, the underlying safety regulations are exactly the same. The B&W mPower SMR will be able to meet regulatory requirements through the robust features of its underground nuclear island architecture, which is being designed to exceed the current NRC safety goal by 2-3 orders of magnitude. In addition, there is no intention or need to weaken NRC regulatory requirements in order to reduce operational and maintenance costs, as the UCS implied. On the contrary, we plan to meet or exceed NRC requirements while simultaneously maintaining competitive costs, by designing the plant itself to be more operationally efficient. For example, we believe the inherently safe and secure design of the B&W mPower nuclear island will require fewer personnel to meet the NRC requirements to safeguard the plant against security threats. Therefore, we have no plans and no need to change or weaken underlying regulatory requirements in order to license the B&W mPower SMR.

Co-location of Multiple Modules at One Site

The UCS also stated:

> *"As we have seen in Fukushima, nuclear plants with multiple reactors that experience severe conditions present extreme challenges. At Fukushima, the need to manage multiple simultaneous crises resulted in what sometimes appeared to be a game of 'whack-a-mole' as the plant operator was forced to shift limited resources from one unit to another as new problems cropped up. These considerations make multiple-reactor sites less attractive from a safety perspective."*

The events at Fukushima were more than anything else the result of plant and site configuration. This statement ignores the inherent differences between SMRs and the Fukushima plant. As explained earlier, the embedding of the entire reactor building, including all necessary core cooling and safety systems, in an underground containment, significantly isolates the reactor from the threats of external events. In addition, each module is embedded in its own individual containment with independent, dedicated safety systems. There is no sharing of safety systems. Finally, due to the reactor's inherently safer design, including small size, low power density, large water inventory and inherent safety systems, reactor safety after a shutdown is not dependent upon immediate assistance from operators or outside help. As stated earlier, for the B&W mPower design, no emergency operator action is required for the first 72 hours to mitigate accidents, allowing operators to focus on managing long-term effects.

Extensive Test Program
We are currently engaged in an extensive test program to provide the NRC in-depth analytical and physical data to evaluate the safety of the B&W mPower reactor. This includes an Integrated Systems Test facility in Bedford, Virginia, with an unfueled, scaled prototype reactor system to demonstrate the thermo-hydraulic characteristics of the reactor. We expect this testing, which represents a significant investment, to demonstrate to the NRC that the B&W mPower reactor will far exceed current safety requirements. We are working with the NRC to ensure that our design meets or exceeds regulatory requirements, and we will continue to do so as we learn more from the events at Fukushima.

The Economics of SMRs: Competitive & Financeable
Market analysis has concluded that the addressable market for SMRs, both in the United States and globally, ranges from 100-125 GWe through 2030, and that, in addition to benefitting from the factors contributing to the resurgence of nuclear power in general, SMRs directly address the key challenges such as financing risk, cost and time certainty, production bottlenecks and expensive grid upgrades associated with the construction of large-scale, traditional nuclear plants. We would not be investing our company's resources in this effort if we did not believe we could produce a competitive product on both a Levelized-Cost-of-Electricity (LCOE) and per-kilowatt (per-kW) basis to serve this meaningful market.

In addition, we have a Consortium of 15 U.S. utilities and an Industry Advisory Council of 26 utilities, both U.S. and international, which demonstrates broad industry interest. In addition to the investment B&W has made, utilities in our Consortium have also invested resources in the B&W mPower development process. We are working closely with our Consortium, Industry Advisory Council, and our Engineering, Procurement and Construction (EPC) partner to validate the economic value of our reactor and incorporate their valuable input on life-cycle costs.

There has been much discussion surrounding the economics of SMRs, particularly concerns that due to the principle of economies of scale, smaller reactors cannot compete with large reactors. This is untrue. The design, size and inherently safe features that ensure that SMRs will raise safety to the next level also enable SMRs to offer the carbon-free advantages of nuclear power in a cost-competitive, more financeable form. This is achievable through a paradigm shift from "economies of scale" to factory assembly of simplified, integral reactors in a manufacturing setting—the next step beyond on-site modular construction. In fact, based on the Navy's successful experience with modular submarine construction, we have engaged a submarine industry leader to provide lessons learned from this effort as part of our B&W mPower design team. Through this paradigm shift, we believe we will be able to offer SMRs to our customers without any cost premium—that we can compete with any new-generation large reactor. In addition, based on our experience manufacturing reactors for both government and commercial customers, we believe we will achieve n^{th}-of-a-kind costs in less than 10 modules, rather than thousands as some SMR opponents have implied. Our utility customers require that SMRs be competitive on a per-kW basis with large reactors. This is achievable through:

- modular, integral design and factory assembly for a fully manufactured product,
- the ability to maintain a skilled workforce in a manufacturing setting,
- improved quality, efficiency and process standardization in factory settings, and
- simplified construction on-site.

In addition, a significant economic advantage of SMRs is the ability to incrementally add individual modules to a site to support load growth and minimize financing risk. Improved financing reduces costs, while individual modules provide utilities the flexibility to replace old fossil plants with carbon-free nuclear power while using existing grid and site assets, further reducing costs. While SMRs require more staff than a similarly sized fossil plant, the replacement of such plants with SMRs simply trades the higher cost of fossil fuels and impact of emissions, as compared to nuclear fuel, for more highly skilled, better paying nuclear jobs.

External Economic Studies: The Value of a Smaller Option

There are several studies available on the economics of SMRs, some with widely varying views of the cost-competitiveness of SMRs. Unfortunately, many of these reach erroneous conclusions. For example, a recent study by the OECD Nuclear Energy Assembly, which is currently receiving attention, concluded that “the investment component of the LUEC [Levelized Unit Electricity Cost] for a SMR would be at least 10-40% higher than in the case of a NPP [Nuclear Power Plant] with a large reactor”. We disagree with this viewpoint. This study was completed without direct input by B&W, and is not consistent with our internal estimates. Any studies that compare estimated SMR costs to large reactor costs are simply comparing estimates to estimates. We have not yet built a new generation large reactor in this country, and therefore it is impossible to compare SMR costs to large reactor costs without making several significant assumptions about the next class of large reactors.

More importantly, this type of comparison assumes that every utility has the same needs, that require the same solution. Not every utility has the capital, grid and water resources to build a large reactor, nor does every utility need capacity of that size. In these cases, which represent numerous utilities across the country, small, more affordable SMRs offer a better solution. In fact, despite the OECD study’s inflated comparative cost estimates, it goes on to conclude that SMRs have significant potential for several market segments, including replacing old fossil plants, grid-limited sites, water-limited sites, and those utilities for whom lower upfront capital investment, lower cost of financing and flexibility are important. It also concludes that “SMRs could be competitive with many non-nuclear technologies.” In short, it validates our value proposition, which is that SMRs offer utilities a more flexible, financeable, competitive carbon-free option.

Public-Private Partnership: Investment in Clean Energy & U.S. Jobs

I will conclude with a discussion of the critical need for the Department of Energy’s (DOE) proposed SMR cost-share program. This program, which would share the costs and risks associated with developing and licensing any new nuclear technology, is critical to the market development and viability of SMRs. Due to the regulatory and policy environment, there is significant risk associated with developing and deploying any first-of-a-kind nuclear technology. A public-private partnership to develop SMRs is necessary to share these risks and make the long-term, significant investment justifiable to shareholders and investors, by showing the government's commitment to the future of nuclear power and SMRs. This will provide a level of certainty critical to market development, competition, and long-term associated investment. In addition, broad market adoption of SMR technology is dependent on a successful first-of-a-kind project. Such projects include significant non-recurring costs, which represent a barrier to deployment of SMRs without a mechanism for public-private partnership.

The DOE has established a goal to reduce emissions from DOE facilities by 28% by 2020. In addition, new Environmental Protection Agency (EPA) regulations are likely to drive the retirement of 25-50 GW of coal-fired baseload generation near-term, based on recent industry projections. Most U.S. SMR vendors, while proactively pursuing development of SMRs, are unable to independently invest at the pace needed to deploy the first SMRs by 2020, or potentially at a pace necessary to ensure a viable business case. Without SMR technology available to provide in-kind baseload power sized to replace these old coal plants, utilities will face grid stability and reliability issues. It is critical that utilities have viable carbon-free options to replace old, baseload coal plants by 2020. To reach this goal of deployment by 2020—a goal driven by government policy and regulation—a public-private partnership to share costs and risks is critical.

This timeline is also critical to maintain the U.S.'s competitive edge in the international nuclear power market. Our international competitors are largely state-owned or subsidized companies making large investments in nuclear technology, including SMRs. There are currently several SMRs being developed internationally, in China, Russia, India, Argentina, South Korea, and elsewhere.

Failing to move forward with this program will not stall the deployment of SMRs in the United States or world-wide, but will simply stymie the U.S. industry's current early mover advantage in SMR technology and manufacturing leadership. Failure to fund an SMR cost-share program will ensure that foreign SMRs (like the South Korean SMART reactor) receive the manufacturing jobs and exporting benefits by selling to U.S. utility customers. At a time when we need to ensure that public policy promotes U.S. competitiveness in technology innovation and leadership, the SMR cost-share program is the conduit to maintain U.S. leadership and create the manufacturing base here instead of overseas. Conversely, the sharing of risks and costs through public-private partnership will ultimately result in a return on investment to government by supporting nuclear technology which can compete in the market without government support or subsidy, while creating U.S. design, supply chain, construction, and operations jobs.

As Ernie Moniz, the Director of MIT's Energy Initiative & Laboratory for Energy and the Environment, testified before this subcommittee, on March 30, 2011, two weeks after the events at Fukushima:

> *"A 2020 SMR option will be available only if we start now, and even then it will be tight. Prior to Fukushima, the Obama administration submitted to the Congress a proposed 2012 budget that would greatly enhance the level of activity in bringing SMRs to market….The program is modest but sensible. Obviously the Federal budget deficit makes it difficult to start any new programs, but a hiatus in creating new clean energy options – be it nuclear SMRs or renewables or advanced batteries – will have us looking back in ten years lamenting the lack of a technology portfolio needed to meet our energy and environmental needs economically or to compete in the global market."*

Closing Comments
Innovative SMRs, like the B&W mPower reactor, have the potential to raise nuclear safety to the next level, while offering America a competitive source of near-term, domestically produced, clean energy. In order to meet President Obama's vision of being 80% carbon-free by 2050, industry needs a practical nuclear option. The President has explicitly acknowledged and endorsed that nuclear should and must be part of the generation portfolio. B&W has heard repeatedly from industry that a near-term light water SMR option is essential to a practical nuclear generation solution. Turning this innovation into reality will depend on leadership and foresight from both the nuclear industry and government through a true public-private partnership. We therefore ask that this Committee support the DOE cost-share program and help maintain our nation's leadership role in nuclear power and clean energy technology.

Thank you for the privilege of testifying today. I am happy to answer any questions the Committee may have.