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A Big Future for Small Nuclear Reactors?

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Abstract: *More and more companies—in the U.S. and abroad—are investing in new commercial nuclear enterprises, chief among them, small modular reactors (SMRs). The SMR industry is growing, with many promising developments in the works—which is precisely why the government should not interfere, as subsidies and government programs have already resulted in an inefficient system for large reactors. Heritage Foundation nuclear policy experts explain how the future for small reactors can remain bright.*

Small modular reactors (SMRs) have garnered significant attention in recent years, with companies of all sizes investing in these smaller, safer, and more cost-efficient nuclear reactors. Utilities are even forming partnerships with reactor designers to prepare for potential future construction. Perhaps most impressive is that most of this development is occurring without government involvement. Private investors and entrepreneurs are dedicating resources to these technologies based on their future prospects, not on government set-asides, mandates, or subsidies, and despite the current regulatory bias in favor of large light water reactors (LWRs).

The result is a young, robust, innovative, and growing SMR industry. Multiple technologies are being proposed that each have their own set of characteristics based on price, fuel, waste characteristics, size, and any number of other variables. To continue this growth, policymakers should reject the temptation to

Talking Points

- Small modular reactors (SMRs) represent an important development in the evolution of commercial nuclear power in the United States.
- SMRs can be built in the United States and could provide important competition in the energy industry that will push technology forward while driving prices lower.
- Their lower up-front capital costs than traditional nuclear power, scalability, and multifunctionality add to the benefits that attract investors.
- Inefficient licensing and rulemaking, a failed nuclear waste management policy, and too much federal government intervention are creating barriers to the SMR progress.
- Most current attempts to promote SMR development rely on government bureaucrats and politicians to decide the future of the industry rather than relying on market forces.
- Instead, the federal government should develop a new, market-based approach that provides a stable regulatory environment, promotes competition, and relies on private investment and sustainable economics.

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offer the same sort of subsidies and government programs that have proven ineffective for large LWRs. While Department of Energy cost-sharing programs and capital subsidies seem attractive, they have yet to net any new reactor construction. Instead, policymakers should focus on the systemic issues that have continued to thwart the expansion of nuclear power in recent years. Specifically, the federal government needs to develop an efficient and predictable regulatory pathway to new reactor certification and to develop a sustainable nuclear waste management strategy.

Why SMRs?

Small modular reactors share many of the attractive qualities of large reactors, such as providing abundant emissions-free power, while adding new features that could make them more appropriate for certain applications, such as providing power to rural communities or for dedicated industrial use. SMRs are not yet positioned to take the place of traditional large LWRs, but they represent an important growth area for the commercial nuclear industry.

Indeed, should the promise of small modular reactors be realized, the technology could transform the nuclear industry. That is because these attributes would potentially mitigate some of the financial and regulatory problems that nuclear energy has recently faced. SMRs potentially cost less (at least in up-front capital), are more mobile and multifunctional, provide competition, and can largely be produced by existing domestic infrastructure.

Lower Costs Up Front. Large reactors are very expensive to license and construct and require massive up-front capital investments to begin a project. Small reactors, while providing far less power than large reactors, can be built in modules and thus be paid for over time. For example, estimates for larger reactors range from $6 billion to $10 billion and must be financed all at once. The Babcock & Wilcox Company's modular mPower reactors, alternatively, can be purchased in increments of 125 megawatts (MW), which would allow costs to be spread out over time. Though cost estimates are not yet available for the mPower reactor, its designers have stated that they will be competitive. This should not be used as a reason to refrain from building larger, 1,000-plus MW reactors. Each utility will have its own set of variables that it must consider in choosing a reactor technology, but given that one of the primary justifications for government subsidies is that the high costs of large reactors puts unacceptable strain on utility balance sheets, an option that spreads capital outlays over time should be attractive.

Safe Installation in Diverse Locations. Some designs are small enough to produce power for as few as 20,000 homes. One such reactor, Hyperion Power's HPM (Hyperion Power Module) offers 25 MW of electricity for an advertised cost of $50 million per unit. This makes the HPM a potential power solution for isolated communities or small cities.[1] The Alaskan town of Galena, for example, is planning to power its community with a small reactor designed by Toshiba, while Fairbanks is looking into a small plant constructed by Hyperion.[2] In addition, Western Troy Capital Resources has stated that it will form a private corporation to provide electric power from small reactors for remote locations in Canada.[3] Public utility officials in Grays Harbor, Washington, have spoken with the NuScale Power company about powering the community with eight small nuclear plants;[4] and Hyperion Power has reported a high level of interest in

1. Jenny Mandel, "Less Is More for Designers of 'Right-Sized' Nuclear Reactors," *Scientific American*, September 9, 2009, at *http://www.scientificamerican.com/article.cfm?id=small-nuclear-power-plant-station-mini-reactor* (January 20, 2011).
2. Stefan Milkowski, "Alaska Eyes Small Reactors," *Earth News*, July 1, 2009, at *http://www.earthportal.org/news/?p=2518* (January 20, 2011).
3. Stephen Heiser, "Western Troy To Try Its Hand at Small Nuclear Reactors," Nuclear Street, August 18, 2009, at *http://nuclearstreet.com/blogs/nuclear_power_news/archive/2009/08/18/western-troy-to-try-its-hand-at-small-nuclear-reactors-1222.aspx#* (January 20, 2011).
4. Stephen Heiser, "Grays Harbor Washington Considers Going with Small Reactors," Nuclear Street, August 20, 2009, at *http://nuclearstreet.com/blogs/nuclear_power_news/archive/2009/08/20/Grays-Harbor-Washington-Considers-Goining-With-Small-Reactors-1850.aspx#* (January 20, 2011).

small nuclear reactor designs from islands around the world.[5]

Using a small nuclear reactor could cut electricity costs in isolated areas since there would be no need for expensive transmission lines to carry power to remote locations.[6] SMRs could also potentially be integrated into existing energy infrastructure. SMRs could be built into old coal plants, for instance. The reactors would replace the coal boilers and be hooked into the existing turbines and distribution lines. According to the Nuclear Regulatory Commission, these modifications could be completed safely since small reactors will likely be easier to control during times of malfunction.[7]

Multi-functionality. SMRs can be used in a variety of applications that have substantial power and heat requirements. The chemical and plastics industries and oil refineries all use massive amounts of natural gas to fuel their operations. Similarly, small reactors could produce the heat needed to extract oil from tar sands, which currently requires large amounts of natural gas. While affordable today, natural gas prices vary significantly over time, so the long-term predictable pricing that nuclear provides could be very attractive. SMRs may also provide a practical solution for desalination plants (which require large amounts of electricity) that can bring fresh water to parts of the world where such supplies are depleting.[8] Perhaps most important, is that SMRs have the potential to bring power and electricity to the 1.6 billion people in the world today that have no access to electricity, and to the 2.4 billion that rely on biomass, such as wood, agricultural residue, and dung for cooking and heating.[9]

Competition. While competition among large nuclear-reactor technologies currently exists, small reactors will add a new dimension to nuclear-reactor competition. Multiple small technology designs are set to emerge on the market. Not only will competition among small reactors create a robust market, it will also provide an additional incentive for large reactors to improve. If smaller reactors begin to capture a share of the nuclear market and the energy market at large, it will drive innovation and ultimately lower prices for both new and existing technologies.

Domestic Production. Although the nuclear industry necessarily shrank to coincide with decreased demand, much of the domestic infrastructure remains in place today and could support the expansion of small-reactor technologies. Although the industrial and intellectual base has declined over the past three decades, forging production, heavy manufacturing, specialized piping, mining, fuel services, and skilled labor could all be found in the United States. Lehigh Heavy Forge Corporation in Bethlehem, Pennsylvania, could build the forges while Babcock & Wilcox could provide the heavy nuclear components, for instance. AREVA/Northrop Grumman Shipbuilding broke ground on a heavy components manufacturing facility last June.[10] Further, a number of companies are expanding manufacturing, engineering, and uranium enrichment capabilities—all in the United States.

5. Mark Clayton, "Backyard Reactors? Firms Shrink the Nukes," *The Christian Science Monitor*, December 29, 2008, at *http://features.csmonitor.com/environment/2008/12/29/backyard-reactors-firms-shrink-the-nukes* (January 20, 2011).
6. Tyler Hamilton, "Is Small the Future of Nuclear Power Generation?" *Toronto Star*, January 5, 2009, at *http://www.thestar.com/Business/article/561553* (January 20, 2011).
7. Rebecca Smith, "Small Reactors Generate Big Hopes," *The Wall Street Journal*, February 18, 2010, at *http://online.wsj.com/article/SB10001424052748703444804575071402124482176.html* (January 20, 2011).
8. Robert Bryce, "Nukes Get Small," *Energy Tribune*, July 16, 2008, at *http://www.energytribune.com/articles.cfm?aid=948* (January 21, 2011); Hyperion Power, "Hyperion Power Generation," at *http://www.hyperionpowergeneration.com/about.html* (January 21, 2011); and Kevin Bullis, "Small Nuclear," *Technology Review*, November 10, 2005, at *http://www.technologyreview.com/energy/15865/?a=f* (January 21, 2011).
9. Hyperion Power, "Community Applications," at *http://www.hyperionpowergeneration.com/product-com.html* (January 21, 2011).
10. Press release, "AREVA, Northrop Grumman Break Ground on AREVA Newport News Facility, Marking Concrete Step in U.S. Nuclear Energy Revival," Northrop Grumman, July 22, 2009, at *http://us.areva.com/home/liblocal/docs/Press%20releases/2009/AREVA_Northrop_Gruman_Newport_News_7_22.pdf* (January 21, 2011).

If SMRs Are So Great, Where Is the Construction?

While some designs are closer to market introduction than others, the fact is that America's regulatory and policy environment is not sufficient to support a robust expansion of existing nuclear technologies, much less new ones. New reactor designs are difficult to license efficiently, and the lack of a sustainable nuclear waste management policy causes significant risk to private investment.

Many politicians are attempting to mitigate these market challenges by offering subsidies, such as loan guarantees. While this approach still enjoys broad support in Congress and industry, the reality is that it has not worked. Despite a lavish suite of subsidies offered in the Energy Policy Act of 2005, including loan guarantees, insurance against government delays, and production tax credits, no new reactors have been permitted, much less constructed. These subsidies are in addition to existing technology development cost-sharing programs that have been in place for years and defer significant research and development costs from industry to the taxpayer.

The problem with this approach is that it ignores the larger systemic problems that create the unstable marketplace to begin with. These systemic problems generally fall into three categories:

1. **Licensing**. The Nuclear Regulatory Commission (NRC) is ill prepared to build the regulatory framework for new reactor technologies, and no reactor can be offered commercially without an NRC license. In a September 2009 interview, former NRC chairman Dale E. Klein said that small nuclear reactors pose a dilemma for the NRC because the commission is uneasy with new and unproven technologies and feels more comfortable with large light water reactors, which have been in operation for years and has a long safety record.[11] The result is that enthusiasm for building non-light-water SMRs is generally squashed at the NRC as potential customers realize that there is little chance that the NRC will permit the project within a time-frame that would promote near-term investment. So, regardless of which attributes an SMR might bring to the market, the regulatory risk is such that real progress on commercialization is difficult to attain. This then leaves large light water reactors, and to a lesser extent, small ones, as the least risky option, which pushes potential customers toward that technology, which then undermines long-term progress, competition, and innovation.
2. **Nuclear Waste Management.** The lack of a sustainable nuclear waste management solution is perhaps the greatest obstacle to a broad expansion of U.S. nuclear power. The federal government has failed to meet its obligations under the 1982 Nuclear Waste Policy Act, as amended, to begin collecting nuclear waste for disposal in Yucca Mountain. The Obama Administration's attempts to shutter the existing program to put waste in Yucca Mountain without having a backup plan has worsened the situation. This outcome was predictable because the current program is based on the flawed premise that the federal government is the appropriate entity to manage nuclear waste. Under the current system, waste producers are able to largely ignore waste management because the federal government is responsible. The key to a sustainable waste management policy is to directly connect financial responsibility for waste management to waste production. This will increase demand for more waste-efficient reactor technologies and drive innovation on waste-management technologies, such as reprocessing. Because SMRs consume fuel and produce waste differently than LWRs, they could contribute greatly to an economically efficient and sustainable nuclear waste management strategy.
3. **Government Intervention**. Too many policymakers believe that Washington is equipped to guide the nuclear industry to success. So, instead of creating a stable regulatory environment where the market value of different nuclear technologies can determine their success and evolution, they

11. Dan Yurman, "NRC Rule—No Rabbits Out of a Hat," The Energy Collective, September 25, 2009, at *http://theenergycollective.com/djysrv/30832/nrc-rule-no-rabbits-out-hat* (January 21, 2011).

choose to create programs to help industry succeed. Two recent Senate bills from the 111th Congress, the Nuclear Energy Research Initiative Improvement Act (S. 2052) and the Nuclear Power 2021 Act (S. 2812), are cases in point. Government intervention distorts the normal market processes that, if allowed to work, would yield the most efficient, cost-effective, and appropriate nuclear technologies. Instead, the federal government picks winners and losers through programs where bureaucrats and well-connected lobbyists decide which technologies are permitted, and provides capital subsidies that allow investors to ignore the systemic problems that drive risk and costs artificially high. This approach is especially detrimental to SMRs because subsidies to LWRs distort the relative benefit of other reactor designs by artificially lowering the cost and risk of a more mature technology that already dominates the marketplace.

How to Fix a Broken System

At the Global Nuclear Renaissance Summit on July 24, 2008, then-NRC chairman Dale Klein said that a nuclear renaissance with regard to small reactors will take "decades to unfold."[12] If Members of Congress and government agencies do not reform their current approach to nuclear energy, this will most certainly be the case. However, a new, market-based approach could lead to a different outcome. Instead of relying on the policies of the past, Congress, the Department of Energy, and the NRC should pursue a new, 21st-century model for small and alternative reactor technologies by doing the following:

- **Reject additional loan guarantees.** Loan guarantee proponents argue that high up-front costs of new large reactors make them unaffordable without loan guarantees. Presumably, then, a smaller, less expensive modular option would be very attractive to private investors even without government intervention. But loan guarantees undermine this advantage by subsidizing the capital costs and risk associated with large reactors. A small reactor industry without loan guarantees would also provide competition and downward price pressure on large light water reactors. At a minimum, Congress should limit guarantees to no more than two plants of any reactor design and limit to two-thirds the amount of any expanded loan guarantee program that can support a single technology. Such eligibility limits will prevent support from going only to a single basic technology, such as large light water reactors.[13]
- **Avoid subsidies.** Subsidies do not work if the objective is a diverse and economically sustainable nuclear industry. Despite continued attempts to subsidize the nuclear industry into success, the evidence demonstrates that such efforts invariably fail. The nuclear industry's success stories are rooted in the free market. Two examples include the efficiency and low costs of today's existing plants, and the emergence of a private uranium enrichment industry. Government intervention is the problem, as illustrated by the government's inability to meet its nuclear waste disposal obligations.
- **Build expertise at the Nuclear Regulatory Commission.** The NRC is built to regulate large light water reactors. It simply does not have the regulatory capability and resources to efficiently regulate other technologies, and building that expertise takes time. Helping the NRC to develop that expertise now would help bring new technologies into the marketplace more smoothly. Congress should direct and resource the NRC to develop additional broad expertise for liquid metal-cooled, fast reactors and high-temperature, gas-cooled reactors. With its existing expertise in light water technology, this additional expertise would position the NRC to effectively regulate an emerging SMR industry.
- **Establish a new licensing pathway.** The current licensing pathway relies on reactor customers to

12. Prepared Remarks of NRC Chairman Dale E. Klein, Global Nuclear Renaissance Summit, Alexandria, VA, July 24, 2008, at *http://www.nrc.gov/reading-rm/doc-collections/commission/speeches/2008/s-08-030.html* (January 21, 2011).
13. Jack Spencer, "Conditions and Policy Reforms Must Accompany Loan Guarantee Boost," Heritage Foundation *WebMemo* No. 2789, February 3, 2010, at *http://www.heritage.org/research/reports/2010/02/conditions-and-policy-reform.*

drive the regulatory process. But absent an efficient and predictable regulatory pathway, few customers will pursue these reactor technologies. The problem is that the legal, regulatory, and policy apparatus is built to support large light water reactors, effectively discriminating against other technologies. Establishing an alternative licensing pathway that takes the unique attributes of small reactors into consideration could help build the necessary regulatory support on which commercialization ultimately depends.[14]

- **Resolve staffing, security, construction criteria, and fee-structure issues by December 31, 2011.** The similarity of U.S. reactors has meant that the NRC could establish a common fee structure and many general regulatory guidelines for areas, such as staffing levels, security requirements, and construction criteria. But these regulations are inappropriate for many SMR designs that often have smaller staff requirements, unique control room specifications, diverse security requirements, and that employ off-site construction techniques. Subjecting SMRs to regulations built for large light water reactors would add cost and result in less effective regulation. The NRC has acknowledged the need for this to be resolved and has committed to doing so, including developing the budget requirements to achieve it. It has not committed to a specific timeline.[15] Congress should demand that these issues be resolved by the end of 2011.
- **Reform waste management.** The federal government's inability to fulfill its legal obligations under the 1982 Nuclear Waste Policy Act has often been cited as a significant obstacle to building additional nuclear power plants. Given nuclear power's potential to help solve many of the nation's energy problems, now is the time to break the impasse over managing the nation's used nuclear fuel. The current system is driven by government programs and politics. There is little connection between used-fuel management programs, economics, and the needs of the nuclear industry. Any successful plan must grow out of the private sector, be driven by sound economics, and provide access to the funds that have been set aside for nuclear waste management.[16] Such an approach would propel the development of SMRs by placing market value on their potential waste management attributes.

Transitioning to a New Era of Nuclear Power

It is an exciting time for the nuclear industry in the United States and around the world, but that excitement could quickly dwindle if Congress and the White House do not usher in a new path forward for nuclear energy. New technologies have the potential to revolutionize how people produce and consume energy, but if the same bureaucratic approach is taken, it will create the same problems of dependency and stagnation that led to the demise of the commercial nuclear industry decades ago. Congress and the Administration have the opportunity to create a robust, competitive market for nuclear power and should implement the necessary reforms to make this happen.

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14. Commissioner William C. Ostendorff, "Small Modular Reactors—Challenges and Opportunities," Nuclear Regulatory Commission, June 28, 2010, at *http://www.highbeam.com/doc/1G1-230098692.html* (January 21, 2011).
15. Nuclear Regulatory Commission, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs," March 28, 2010, at *http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2010/secy2010-0034/2010-0034scy.html* (January 21, 2011).
16. Jack Spencer, "A Free-Market Approach to Managing Used Nuclear Fuel," Heritage Foundation *Backgrounder* No. 2149, June 23, 2008, at *http://www.heritage.org/Research/EnergyandEnvironment/bg2149.cfm.*

APPENDIX: SMALL REACTOR DESIGNS

A number of companies are developing or have already developed small reactors; each has unique features and varying megawatt capacity. These companies include NuScale Power, Hyperion Power Generation, Toshiba, PBMR, Ltd, General Atomics, Babcock & Wilcox, General Electric, and TerraPower. While the following list is not comprehensive, it provides a general description of SMR activity.

- **NuScale Power** is developing a 45 MW electric small light water reactor that measures about 60 feet in length and 14 feet in diameter. NuScale's technology is scalable; each module has its own combined containment vessel and reactor system, and its own designated turbine-generator, which allows a single facility to have up to 24 units. In this type of plant, one unit can be removed and taken out of service without affecting the operation of the other modules. NuScale is well into the stages of development and expects to commercialize its system and technology by 2015 or 2016.[17] It has submitted its design to the NRC, and an official design certification application is expected to be submitted in early 2012.[18]
- **Hyperion Power Generation**, in collaboration with Los Alamos National Laboratory, is developing a 25 MW electric reactor that would produce enough electricity to power 20,000 homes. Hyperion is looking to commercialize the reactors for remote locations as soon as 2015. According to Hyperion, the reactors are the size of a hot tub and will be buried under the ground and it is impossible for them to melt down or be broken down into weapons due to their fuel and reactor design. Similar to the NuScale design, Hyperion's modules can be coupled together to produce even more power.[19] Hyperion and the Savannah River National Laboratory signed an agreement in September stating that Hyperion will build a $50 million demonstration reactor at the site, with most of the funding coming from private sources. They hope to complete construction by 2017 or 2018.[20] The Hyperion Power Module is also being considered for application in naval propulsion.[21]
- **Toshiba**'s 4S design (Super-Safe, Small, and Simple) is a sodium-cooled 10 MW reactor that has often been called the "nuclear battery" because it does not require refueling.[22] The NRC is currently reviewing Toshiba's pre-application for design certification, which is expected to be submitted by 2012.[23]
- **Pebble Bed Modular Reactor, Ltd (PBMR)** is a consortium based in South Africa working to develop a 165 MW electric, pebble-bed modular reactor, named after the tennis-ball-sized fuel pebbles that make up its core.[24] Known as high-temperature gas-cooled reactors, pebble-bed reactors are helium-cooled

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17. NuScale Power, "Overview of NuScale's Technology," at *http://www.nuscalepower.com/ot-Scalable-Nuclear-Power-Technology.php* (January 21, 2011).
18. Nuclear Regulatory Commission, "NuScale," November 3, 2010, at *http://www.nrc.gov/reactors/advanced/nuscale.html* (January 21, 2011).
19. Hyperion Power Generation, "Clean, Safe, Affordable Power: Where You Need it, When You Need it," at *http://nomoretowers.org/Documents/Hyperion%20Nuclear%20Power%20Generation.htm* (January 21, 2011).
20. "Hyperion to Build First Small Nuclear Reactor at US DOE Complex," Platts, September 10, 2010, at *http://www.platts.com/RSSFeedDetailedNews/RSSFeed/HeadlineNews/Nuclear/8939538* (January 21, 2011).
21. Press release, "Shipping and Power Experts Join Forces to Explore the Potential for Nuclear Power to Propel Future Generations of Commercial Tankers," Hyperion Power and Lloyd's Register, November 15, 2010, at *http://www.hyperionpowergeneration.com/news/press-Lloyds.pdf* (January 21, 2011).
22. Rod Adams, "Nuclear Power for Galena, Alaska," *Atomic Insights*, March 20, 2005, at *http://www.atomicinsights.com/AI_03-20-05.html* (January 21, 2011).
23. Nuclear Regulatory Commission, "Super-Safe, Small and Simple (4S)," November 3, 2010, at *http://www.nrc.gov/reactors/advanced/4s.html* (January 21, 2011).

and fueled by low-enriched uranium. Since the pebble-bed reactor is not dependent on water as a coolant, the reactor is attractive for geographic locations lacking a large body of water.[25] Current plans are to apply for an NRC design certification in 2013.

- **General Atomics** (GA) is in the early stages of a 12-year, $1.7 billion endeavor to design, secure regulatory approval for, and build its first EM_2 reactor. Similar to other GA designs, the EM_2 has an inherent passive safety system and would require refueling only about every 30 years.[26] With the helium-cooled EM_2 that does not require a nearby water source, GA is looking to employ fast reactor technology and use spent fuel and nuclear waste to create power. It would do all of this without traditional reprocessing of spent fuel. The reactor might be useful in the fertilizer or chemical processing industries because the 240 MW electric reactor operates at very high temperatures.[27] Other potential industrial applications include desalination and petroleum refining.[28]
- **The Babcock & Wilcox Company** is developing a smaller version of the typical light water reactors currently in operation in the United States called mPower. Since B&W is scaling down a proven technology, licensing and commercialization will be more fluid than newer designs. B&W's design is scalable to provide electricity production, depending on the demand needed. [29] B&W hopes to submit a license by 2012 and commence construction by 2015.[30] Recently, the Tennessee Valley Authority began a dialogue with the Nuclear Regulatory Commission to seek regulatory approval for mPower units to be built at its Clinch River nuclear plant in Oak Ridge.[31]
- **General Electric Hitachi**'s (GEH) Power Reactor Innovative Small Modular (PRISM) is a sodium-cooled fast reactor that is modular and scalable and will provide 311 MW of electricity.[32] PRISM is part of GEH's Advanced Recycling Center (ARC), which combines used fuel recycling with advanced reactor technology to extract 100 times more energy from nuclear fuel than current U.S. practice and result in far less waste for long-term disposal.[33] The Nuclear Regulatory Commission has already conducted a prelicensing review of the reactor and GEH hopes to submit an application to the NRC in early 2012 to permit the construction of a PRISM.

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24. For more information, see PBMR homepage at *http://www.pbmr.co.za* (January 25, 2011).
25. Rod Adams, "PBMR Update," *Atomic Insights*, June 7, 2005, at *http://www.atomicinsights.com/AI_06-07-05.html* (January 21, 2011).
26. "Energy Multiplier (EM^2) Quick Facts," General Atomics, *http://www.ga.com/energy/em2/pdf/FactSheet_QuickFactsEM2.pdf* (January 21, 2011).
27. Mike Freeman, "Company Has Plan for Small Reactors," *The San Diego Union-Tribune*, February 24, 2010, at *http://www.signonsandiego.com/news/2010/feb/24/company-has-plan-for-small-reactors* (January 21, 2011).
28. Rebecca Smith, "General Atomics Proposes a Plant that Runs on Nuclear Waste," *The Wall Street Journal*, February 22, 2010, at *http://online.wsj.com/article/SB10001424052748703791504575079370538466574.html* (January 21, 2011).
29. "McDermott B&W Unit to Unveil Small Nuclear Reactor," Reuters, June 10, 2009, at *http://www.reuters.com/article/rbssOilRelatedServicesEquipment/idUSN1011888520090610* (January 21, 2011),and World Nuclear Association, "Small Nuclear Power Reactors," at *http://www.world-nuclear.org/info/inf33.html* (January 21, 2011).
30. Katherine Ling, "Company Calls New Small Nuclear Reactor a 'Game Changer,'" *The New York Times*, June 10, 2009, at *http://www.nytimes.com/gwire/2009/06/10/10greenwire-company-calls-new-small-nuclear-reactor-a-game-45123.html* (January 21, 2011).
31. Tom Lamar, "TVA Interested in the B&W mPower Small Modular Reactors," Nuclear Street, November 12, 2010, at *http://nuclearstreet.com/nuclear_power_industry_news/b/nuclear_power_news/archive/2010/11/12/tva-interested-in-the-b_2600_w-mpower-small-modular-reactors-111204.aspx* (January 21, 2011).
32. GE Hitachi, "Advanced Recycling Center—Solving the Used Nuclear Fuel Dilemma," Technology Update, 2009, at *http://www.gepower.com/prod_serv/products/nuclear_energy/en/downloads/Advanced_Recycling_Center_Technology_Update_-_GEA17804[2].pdf* (January 21, 2011).

- **TerraPower**, an offshoot of the company Intellectual Ventures, is designing a 350 to 500 MW electric reactor that uses traveling wave reactor (TWR) technology.[34] Bill Gates is investing in TerraPower with Toshiba to move this technology forward.[35] The technology's most attractive feature is that it is fueled by depleted uranium, left over from the enrichment process or spent nuclear fuel. A small amount of low-enriched uranium jump-starts the process, but the reactor makes and consumes its own fuel throughout its lifespan and needs refueling only every 50 to 100 years.[36] TerraPower is unique in that it has already spent millions on research and development and recently raised another $35 million. [37] TerraPower president John Gilleland says the reactor technology could "represent a nearly infinite supply of low-cost energy, carbon-free energy for the world."

33. Press release, "GE Hitachi Nuclear Energy's Advanced Recycling Center Recognized for Its Potential to Make Energy out of Used Nuclear Fuel," General Electric, October 14, 2010, at *http://www.genewscenter.com/Press-Releases/GE-Hitachi-Nuclear-Energy-s-Advanced-Recycling-Center-Recognized-for-Its-Potential-to-Make-Energy-out-of-Used-Nuclear-Fuel-2bae.aspx* (January 21, 2011).
34. Katie Fehrenbacher, "TerraPower: How the Traveling Wave Nuclear Reactor Works," Gigaom, February 15, 2010, at *http://gigaom.com/cleantech/terrapower-how-the-travelling-wave-nuclear-reactor-works/* (January 21, 2011).
35. Karl Burkart, "Bill Gates Bets on Next-Gen Nuclear," Forbes.com, March 24, 2010, at *http://www.forbes.com/2010/03/24/nuclear-power-innovation-technology-ecotech-bill-gates.html* (January 21, 2011).
36. Shigeru Sato, "Toshiba, Bill Gates' TerraPower May Develop Reactor (Update 1)," Bloomberg Businessweek, March 22, 2010, at *http://www.businessweek.com/news/2010-03-22/toshiba-bill-gates-s-terrapower-may-develop-reactor-update1-.html* (January 21, 2011).
37. Peter Behr, "A Reactor that Burns Depleted Fuel Emerges as a Potential 'Game Changer,'" *The New York Times*, February 23, 2010, at *http://www.nytimes.com/cwire/2010/02/23/23climatewire-a-reactor-that-burns-depleted-fuel-emerges-a-72189.html* (January 21, 2011).