Rescuing the Nuclear Renaissance: Why the Military Should Adopt Small Modular Reactors

Alex Hokenson*

In the mid-2000s, the nuclear power industry regained life after decades of cancelled reactor plans and investor uncertainty following the nuclear accidents and energy market disruptions of the 1970s and 1980s.[1] In response to rising fossil fuel costs, increasing U.S. Environmental Protection Agency ("EPA") regulation of coal-fired power plants, concerns over global warming, and the introduction of innovative new reactor designs, industry predicted a "nuclear renaissance."[2] Nuclear power held the promise of delivering reliable, emissions-free power capacity to replace aging coal facilities on a far larger scale and faster timeline than renewable sources alone could deliver.[3]

Small modular reactor ("SMR") technology held particular promise. SMRs are assembled in a factory and delivered by truck or rail, thereby avoiding the costly process of constructing reactors on-site.[4] The small scale of these reactors meant that they could more easily incorporate passive cooling systems, and thus, would neither require the large, expensive cooling systems nor pose the same degree of safety concerns created by large-scale reactors.[5] The modular nature also meant that the number of reactors at a single plant could be increased to meet a utility's growing demand over time rather than the traditional practice where a utility must attempt to predict electrical demand decades into the future and invest a massive initial sum in constructing a large, single reactor.[6] The U.S. Department of Energy ("DOE") recognized the potential of SMR in 2008 and has provided a variety of incentives to industry to encourage its development.[7]

As SMR research and development progressed, however, the favorable climate surrounding nuclear power disappeared. The falling price of natural gas in particular had a negative impact on utility interest in pursuing the long, complicated process of planning future nuclear projects.[8] Despite involving a decades-old reactor design, the 2012 Fukushima-Daiichi meltdown in Japan spurred worldwide skepticism toward new nuclear projects, with the German government going so far as abandoning nuclear power entirely.[9] In another setback for the industry, the U.S. Court of Appeals for the D.C. Circuit ordered the Nuclear Regulatory Commission ("NRC") in 2012 to stop issuing licensing permits until it addressed environmental and safety concerns associated with the Yucca Mountain impasse and the long-term storage of spent nuclear fuel.[10]

While nuclear power and SMR have significant advantages, several major obstacles have made private sector investment difficult. Customer concern about bearing the risks and costs of building and certifying new reactors is a major obstacle to developing nuclear generation.[11] The cur-

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1. Though total nuclear power output has increased due to upgrades and greater capacity at existing reactors, there was a long period where new reactors were not being built. *See* Roland M. Frye Jr., *The Current "Nuclear Renaissance" in the United States, Its Underlying Reasons, and Its Potential Pitfalls*, 29 Energy L.J. 279, 279 (2008) ("The nuclear renaissance is indeed a reality within the United States today. This is apparent from the number of nuclear plant construction applications . . . .").
2. *Id.*
3. *Id.* at 290 (noting that many prominent environmentalists previously opposed to nuclear power came to recognize its value as an alternative to coal generation).
4. *See* Robert Bryce, *Nukes Get Small*, Energy Trib. (July 16, 2008), http://www.energytribune.com/1246/nukes-get-small#sthash.XjtYgQRT.dpbs.
5. *See id.*
6. *See id.*
7. In addition to loan guarantees, DOE spent approximately $70 million in 2013 to promote the development and certification of SMR designs. *Small Modular Reactors*, U.S. Dep't Energy, www.energy.gov/ne/nuclear-reactor-technologies/small-modular-nuclear-reactors (last visited Feb. 10, 2015).
8. Mark Holt, Cong. Research Serv., RL33558, Nuclear Energy Policy 4 (2014) ("A more recent obstacle to nuclear power growth has been the development of vast reserves of domestic natural gas from previously uneconomic shale formations . . . .").
9. Daniel Aldrich, *Nuclear Power's Future in Japan and Abroad: The Fukushima Accident in Social and Political Perspective*, ParisTech Rev. (Aug. 25, 2011), http://www.paristechreview.com/2011/08/25/nuclear-fukushima-accident-social-political-perspective.
10. New York v. Nuclear Regulatory Comm'n, 681 F.3d 471, 483 (D.C. Cir. 2012); *see also* In re Calvert Cliffs Nuclear Project, LLC, 76 N.R.C. 63, 66–67 (2012) ("[I]n recognition of our duties under the law, we will not issue licenses dependent upon the Waste Confidence Decision or the Temporary Storage Rule until the court's remand is appropriately addressed.").
11. David Solan et al., Energy Policy Inst., Economic and Employment Impacts of Small Modular Reactors 45 (2010), http://caesepi.org/wp-content/uploads/2016/02/economic-and-employment-impacts-of-smrs.pdf

rent historic low price of natural gas has also discouraged commercial investors from pursuing the long-term expenses associated with nuclear power.[12] More than any other factor, however, the deregulation of energy markets and the resulting move away from traditional vertically-integrated utilities to merchant energy sellers has disincentivized the long-term investments and higher costs of nuclear power.[13] Five nuclear reactors are in various stages of development in regulated energy markets, while there are currently no new projects in deregulated merchant markets.[14]

The U.S. military is uniquely positioned to benefit from adopting SMR. Numerous military installations rely on imported fuel, which is not only expensive and carbon-intensive, but must sometimes be transported through warzones. SMR could meet the military's energy demand, and avoid high transport risk.[15] The idea of putting SMR's on military installations is not new. In recent years, the proposal has received support from commentators, policy makers in the military and nuclear industry, as well as Congress.[16] The military is a logical customer for SMR, and the U.S. Department of Defense ("DoD") has studied the feasibility of adopting SMR.[17] Given the expense and complexity of beginning a major appropriations program, however, its adoption has little chance of seriously moving forward without further legislative efforts, especially during the current period of major spending cuts.[18] With military adoption, a new legal regime tying military SMR development to the commercial reactor design certification process could be the government's best mechanism to encourage the commercial development of SMR. While the military's traditional exemption from NRC regulation has long been an advantage in limiting costs and delays in its nuclear programs, requiring DoD to follow NRC commercial regulations (particularly those related to the design certification stage) for a new military SMR program would help to allay public safety concerns and enable the commercial nuclear industry to avoid an expensive duplication of effort.

Part I of this Note will explore the regulatory framework governing commercial and military nuclear power. Part II will discuss the background and advantages of SMR technology. Part III will discuss the military's history of nuclear power generation. Part IV will discuss the military's current reliance on fossil fuels and the civilian power grid, and the disadvantages of these energy sources. Part V will offer a proposal recommending appropriations for a new military SMR program along with revisions to the current regulatory framework that would enable the commercial industry to benefit from military efforts. Part VI will discuss the military benefits of adopting SMR for its power needs. Part VII will discuss how the commercial nuclear industry would benefit from military adoption of SMR. Part VIII will address issues and concerns raised by military SMR adoption, and Part IX will conclude by discussing the proposal in light of the challenges.

Ultimately, Section 2513 of title 50 of the U.S. Code and section 2121 of title 42, which exempts all defense-related nuclear projects from NRC licensing requirements, should be amended to require the proposed program of land-based military SMR power plants to obtain NRC design certification in order to enable commercial industry to benefit from a pre-approved design and initial manufacturing set-up costs. Such a program would be consistent with existing U.S. policy; the DOE has already made promoting SMR a priority by committing one billion dollars in loan guarantees and research grants to commercial utilities and reactor manufacturers.[19] The failure to undertake a military SMR program would risk not seeing the fruition of the investment that the government has already made in the technology's development.[20] A military SMR program would hardly be a total solution for the problems facing commercial adoption of SMR and the broader issues facing the nuclear industry as a whole, but it could be an important early step to its revival.[21]

("The investment community has long taken a wait-and-see attitude toward the nuclear power industry. Explicit government support for SMRs will have an impact on desirability in the sector . . . .").

12. Mark Chediak, *Gas Price Drop Raises Risk for Aging Coal, Nuclear Power*, Bloomberg, http://www.bloomberg.com/news/articles/2015-01-07/gas-price-drop-raises-risk-for-endangered-coal-and-nuclear-power (last updated Jan. 7, 2015).
13. Telephone Interview with Brian Harris, Senior Att'y, Nuclear Regulatory Comm'n Office of Gen. Counsel (Jan. 9, 2015); *see also* Edward Kee, *Can Nuclear Succeed in Liberalized Power Markets?*, World Nuclear News (Feb. 4, 2015), www.world-nuclear-news.org/V-Can-nuclear-succeed-in-liberalized-power-markets-0420152.html. Traditional vertically-integrated utilities maintain that nuclear is beneficial for customers because it generates reliable base load and provides an alternative energy supply. Kee, *supra*. The high up-front capital costs are recoverable through cost-of service regulation. *Id.*
14. E-Mail from Larry Brown, Prof'l Instructor in Atomic Energy Law, The George Wash. Univ. Law Sch., to author (Apr. 3, 2015, 12:37 PM EST) (on file with author).
15. A report commissioned by the U.S. Department of Defense to study SMR feasibility on military installations noted that a 40 MW SMR plant could fully meet the energy needs of approximately ninety percent of military installations, and the largest installations' needs could be met by a 160 MW plant. Marcus King et al., Feasibility of Nuclear Power on U.S. Military Installations, Ctr. for Naval Analyses 23 (2011), *available at* https://www.cna.org/CNA_files/PDF/D0023932.A5.pdf.
16. Richard B. Andres & Hanna L. Breetz, *Small Nuclear Reactors for Military Installations: Capabilities, Costs, and Technological Implications*, Strategic F., Feb. 2011, at 1, ndupress.ndu.edu/Portals/68/Documents/stratforum/SF-262.pdf.
17. While noting the associated risks and costs of nuclear power, the 2011 report favorably evaluated the economic and technical feasibility of SMR for military installations. King et al., *supra* note 15, at 53–54.
18. *Id.*
19. While these incentives are not limited to SMR, SMR has consistently received support and funding in DOE's efforts to support advanced nuclear technology. Ethan Howland, *DOE Plans Loan Guarantees for "Advanced" Nuclear*, CQ Roll Call (Sept. 30, 2014), 2014 WL 4825224. Energy Secretary Moniz has specifically mentioned developing SMR in recent speeches as a key part of the Obama Administration's "all of the above" strategy. Ernest Moniz, *Secretary Moniz's Remarks at the 2015 Carnegie International Nuclear Policy Conference*, Energy.gov (Mar. 23, 2015), energy.gov/articles/secretary-monizs-remarks-2015-carnegie-international-nuclear-policy-conference-delivered.
20. *See* Howland, *supra* note 19.
21. Additional reforms to adjust the current nuclear regulatory scheme to take the smaller scale and reduced risks of SMR projects into account would also help

I. Regulatory Framework for Nuclear Power

The current regulatory framework governing nuclear power in the United States was established by the Atomic Energy Act of 1954 ("AEA"),[22] which split jurisdiction over nuclear regulation between defense-related and commercial activity within the newly formed Atomic Energy Commission.[23] The Nuclear Energy Reorganization Act of 1974 modified this framework by creating the NRC and the short-lived Energy Research and Development Administration ("ERDA"), which was replaced in 1977 by the newly formed DOE.[24] The NRC was given the authority to license and regulate the growing commercial nuclear power industry while the DOE retained responsibility for promoting commercial nuclear power and directing the defense-related nuclear activities outside of the NRC's jurisdiction in close coordination with the military.[25] Chapter IX of the AEA governs military nuclear activities and gives nuclear activities related to national security a broad exemption from regulation by the NRC.[26] Section 2513 of title 50 of the U.S. Code further clarified this exemption by prohibiting the use of DoD funding for NRC licensing fees.[27] Military and defense-related DOE programs are also exempt from NRC licensing requirements for nuclear waste storage.[28] This exemption is significant, given the ongoing difficulties with storing commercial nuclear waste.[29]

The complete exemption of military nuclear activities from NRC oversight made sense for a variety of reasons. Military leaders argued that nuclear weapons and nuclear-powered vessels needed to be kept secret and retain independence in the interest of national security.[30] The increasingly controversial commercial nuclear power sector, meanwhile, needed transparency, a credible process for challenging licensing decisions, protection for whistleblowers, and engagement with civilian stakeholders to address growing societal concerns about nuclear safety, siting, and regulation.[31] As a matter of policy, the DOE defense-related nuclear programs closely adhered to NRC safety guidelines when possible, but freely departed whenever the particular needs of a military program deviated from those of commercial projects.[32]

With its mandate to regulate the safety of commercial nuclear power, the NRC developed a rigorous approval process to review applications for proposed nuclear power plants.[33] The initial stage of this process is usually the standard design certification, where NRC engineers evaluate a proposed reactor design and third parties may raise design-related objections, rather than objections based on the suitability of a particular site for a nuclear reactor such as proximity to sensitive local environmental or residential concerns.[34] Once a design is approved, it may then be used for multiple power plant locations over a fifteen-year period.[35] The next stage of the licensing process is the combined operating license ("COL"), which combines the previously separate construction permit and operating license for a proposed nuclear power plant.[36] Unlike the design certification stage, which focuses on the safety of a particular design that will potentially be used in several locations, the COL stage addresses concerns over the siting and appropriateness of a particular proposed plant.[37] Each stage of the licensing process (design certification, COL, early site permit) is a lengthy and expensive process that typically lasts several years, both in preparing the application and in handling the inevitable litigation that follows.[38]

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encourage the commercial adoption of the technology, but this Note will not address issues outside of the military's potential role in spurring the industry. Telephone Interview with Brian Harris, *supra* note 13.

22. Atomic Energy Act of 1954, 68 Stat. 919, 42 U.S.C. §§ 2011–2296.
23. 42 U.S.C. § 2121(a) (granting jurisdiction over military applications of nuclear power to AEC).
24. J. Samuel Walker & Thomas R. Wellock, U.S. Nuclear Regulatory Comm'n, A Short History of Nuclear Regulation 1946–2009, at 24 (2010).
25. Congress felt that it was a conflict of interest for an agency responsible for promoting nuclear power to also regulate itself. *Id.* While technically a civilian agency, the DOE (and its predecessor agencies, the AEC and ERDA), work in close coordination with the DoD on defense-related projects. As an example of this relationship, Admiral Rickover, the first head of the Naval Reactors Branch, was given almost complete autonomy to direct the Navy's nuclear program and exercised dual authority as both a Navy admiral and an AEC senior official. Richard G. Hewlett & Jack M. Holl, Atoms for War and Peace 1953–1961: Eisenhower and the Atomic Energy Commission 186 (1989). After Rickover's tenure ended, an executive order formally established the Director of the Naval Nuclear Propulsion Program as both a DOE and Navy official, to be jointly appointed by both agencies, and given broad DOE & military authority to run the program. Exec. Order No. 12,344, 47 Fed. Reg. 4979 (Feb. 1, 1982).
26. 42 U.S.C. § 2121.
27. "None of the funds authorized to be appropriated by the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1981," Pub. L. No. 96–540, 94 Stat. 3197, "or any other Act may be used for any purpose related to licensing of any defense activity or facility of the Department of Energy by the Nuclear Regulatory Commission." 50 U.S.C. § 2513.
28. Charles H. Montange, *Federal Nuclear Waste Disposal*, 27 Nat. Resources J. 309, 391 (1987) (noting that defense-related nuclear waste sites are exempt from the Energy Reorganization Act of 1974, which requires that facilities storing commercial nuclear waste secure NRC licenses to construct and operate).
29. *Id.* at 400 (discussing the current impasse over Yucca Mountain and stalled efforts to build a long-term waste storage facility for commercial nuclear waste).
30. *See* Alice Buck, U.S. Dep't of Energy, A History of the Energy Research and Development Administration 11 (1982).
31. *See* Walker & Wellock, *supra* note 24, at 77.
32. The need for secrecy and the use of more highly enriched nuclear fuel have been common areas of departure. Telephone Interview with Brian Harris, *supra* note 13.
33. Office of Pub. Affairs, U.S. Nuclear Regulatory Comm'n, Nuclear Power Plant Licensing Process 1 (2004).
34. *See id.* at 8 ("The NRC can certify a reactor design for [fifteen] years through the rulemaking process, independent of a specific site.").
35. *Id.*
36. *Id.* at 9; 10 C.F.R. §§ 52.71–52.110. Design certification can also be incorporated into this COL process if it has not already been approved through the standard design certification process; this would, however, add to the time and cost for licensing an individual plant.
37. Siting may be addressed in the COL process, but there is also an alternative certification called the early site permit, which allows earlier review and approval of a location's suitability for a future reactor independent of a specific plant design or COL application (the early site permit may be extended up to forty years after being granted). 10 C.F.R. §§ 52.12–52.39.
38. The NRC's licensing process typically takes years to complete given agency review procedures and outside legal challenges at different stages. Telephone Interview with Brian Harris, *supra* note 13.

II. Small Modular Reactor Technology

A small modular reactor is a nuclear reactor which produces 300 megawatts ("MW") or less of electric power.[39] SMR's are essentially smaller, scaled-down versions of larger reactors with similar safety concerns.[40] Some current SMR designs imitate uranium-fueled light water reactors used by larger commercial plants, though there are also more advanced designs.[41]

SMRs represent a major shift from the traditional large-scale reactors favored by utilities since the 1950s.[42] Early on, large-scale reactors presented commercial utilities with an advantage; one plant could supply enormous amounts of electricity (500 to 1400 MW) for decades with minimal fuel costs.[43] The massive scale of these projects posed significant disadvantages, however, which became clearer with time. Their sheer size and greater thermal energy output make large reactors more difficult to cool. Large reactors require complex cooling systems, as well as operational risk and cost.[44] Also, large reactors must be assembled on-site, which takes several years and costly construction.[45] Size makes decommissioning a similarly difficult and expensive process, because a large reactor must be shuttered for years before it can be disassembled and removed.[46] Large reactors also force investors to forecast electricity demand decades into the future. Once built, it is extremely difficult to scale output up or down, should the market require more or less electricity.[47] All of these disadvantages—combined with the negative perception created by nuclear accidents in the 1970s and 1980s, the lengthy and expensive licensing process, increasing regulation, and instability in the energy market—led to a major shift away from constructing new nuclear plants.[48]

By contrast, SMR's main disadvantage is its comparatively low output. Where upfront licensing costs are the same, low output makes SMR less attractive to utilities.[49] Despite this greatly reduced output, SMR has several significant advantages. SMRs can be built in a central manufacturing facility and transported fully assembled by truck or rail to a site, greatly reducing the cost of construction and the need for on-site fueling.[50] SMRs have several features which offer safety advantages over larger reactors—lower power output and reduced cooling requirements allow SMRs to utilize simplified passive cooling systems which do not rely on external power, while their small size allows them to be buried completely which greatly simplifies security and containment.[51] Additionally, decommissioning cost and complexity is significantly reduced for the same reason that installation is easy; the entire reactor assembly can be loaded and safely transported to a disposal site at the end of its service life.[52] The modular nature of the reactors also allows plants to scale up generation over time by adding new reactors on-site in response to changing energy demand.[53] The smaller size and reduced cost also makes SMR an attractive option for smaller cities and remote regions that would not be able to support a traditional large-scale reactor.[54]

Despite the continuing bipartisan support for greater commercial development of nuclear from Congress and successive administrations, these efforts remain largely stalled as most utilities have cautiously avoided investing in new nuclear plants and no SMR design has yet been certified.[55]

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39. Solan et al., *supra* note 11, at 7.
40. Due to inherent inefficiencies, a reactor's electrical power output is roughly a third of its thermal output, so the largest within this range would still produce a great deal of heat (e.g., a reactor producing 300 MW of electricity would produce 900 MW of thermal energy). Telephone Interview with Brian Harris, *supra* note 13.
41. This Note will not go into depth on the comparative technical advantages of these reactor types and instead focuses on the common features shared by SMRs. There are several different "Generation IV" reactor designs that are in various stages of development, including sodium-cooled fast reactors, gas-cooled fast reactors, and molten-salt reactors, which use different coolants and have various advantages and drawbacks on fuel costs, economics, complexity and safety. A scaled-down version of the light water reactors currently used by the U.S. nuclear industry, however, has the greatest potential for commercial development in the short term as the industry and the NRC already have decades of experience working with them. *See* John A. Bewick, *Next-Gen Nuclear*, Pub. Util. Fort., 30, 34 (2014) (comparing several competing Generation IV reactor designs).
42. *See* Walker & Wellock, *supra* note 24, at 26–27.
43. *Id.*
44. The failure of these cooling systems can lead to radioactive material escaping the reactor containment and has been the cause of high profile nuclear failures (though it should be noted that the nuclear industry and the NRC have been very successful at preventing such incidents). *See* Aldrich, *supra* note 9; *but see* Edwin Lyman, Union of Concerned Scientists, Small Isn't Always Beautiful: Safety, Security, and Cost Concerns About Small Modular Reactors 9 (2013) ("One attraction of SMRs is their ability to rely on passive natural convection for cooling, without the need for fallible active systems, such as motor-driven pumps, to keep the cores from overheating. The approach is not unique to SMRs . . . . However, it is generally true that passive safety features would be more reliable for smaller cores with lower energy densities.").
45. William Atkinson, *The Incredible Shrinking Reactor*, Pub. Util. Fort., May 2010, at 50–51.
46. *See* Walker & Wellock, *supra* note 24, at 67–68; Lisa Song, *Decommissioning a Nuclear Plant Can Cost $1 Billion and Take Decades*, Reuters (June 13, 2011), http://www.reuters.com/article/idUS178883596820110613; *see also* National Nuclear Laboratory, Small Modular Reactors: Their Potential Role in the UK 7 (July 2012) ("The modular nature of the [SMR] reactor components not only assists in the construction of the plant, but will also ease the decommissioning timescales. With smaller modules, the ability to dispose of the entire unit could be feasible, including in the case of the cartridge type spent fuel.").
47. "SMRs are better suited to match demand growth by incrementally increasing supply. In stable or predictable market conditions where long-term planning is feasible, the modularity of SMRs promotes 'scalability,' while in uncertain market conditions this feature will enhance the 'adaptability' of plant deployment." Solan et al., *supra* note 11, at 10 (citation omitted); *but see* Lyman, *supra* note 44, at 11 (noting that concentrating multiple reactors at the same site could potentially create complications in emergency response, and that the proposed sharing of infrastructure by multiple reactors could result in an incident at one reactor quickly spreading to the others).
48. *See* Walker & Wellock, *supra* note 24, at 67; *see also* Joseph P. Tomain Constance, *Nuclear Transition: From Three Mile Island to Chernobyl*, 28 Wm. & Mary L. Rev. 363, at 363–68, 376, 388 (1987).
49. *Small Modular Reactors*, *supra* note 7.
50. *Id.*
51. *See id.* The Fukushima disaster was triggered when generators powering the plant's cooling system failed and the reactor overheated—though newer large reactors also incorporate passive safety features that very effectively lessen this risk. *See* Inst. of Nuclear Power Operations, Special Report on the Nuclear Accident at Fukushima Daiichi Power Station 6–9 (2011).
52. *Small Modular Reactors*, *supra* note 7.
53. NuScale's reactor is designed to allow one to twelve reactors to be built on one facility. *Frequently Asked Questions*, NuScale Power, http://www.nuscalepower.com/about-us/faqs.
54. *See* George D. Brinks, Ctr. for Strategic & Int'l Studies, SMR Deployment Faces Challenges Despite National Interest: A Summary of Findings From the November 14 CSIS Workshop on SMRs 2 (2013).
55. Pam Radtke Russell, *NuScale to Receive DOE SMR Support; NRC Says Design Approval Could Be Slow*, CQ Roll Call (Dec. 13, 2013), 2013 WL 6551265.

The Energy Policy Act of 2005 created a number of incentives to encourage the construction of new nuclear plants, including loan guarantees, tax breaks, and funding to promote the development of advanced nuclear designs, which includes SMR along with other advanced technologies applicable to both SMRs and traditionally scaled reactors.[56] As part of the 2005 Energy Policy Act's provision to support the development of advanced reactor technology, the DOE solicited design certification applications for SMR and received interest from several companies developing SMR designs.[57] After reviewing several competing designs, DOE awarded Babcock & Wilsox and NuScale over $200 million dollars each in grants to continue work on their design certification efforts.[58] As an incentive to commercial utility customers, the DOE announced in 2014 that it would offer over seven billion dollars in loan guarantees to help finance the licensing process for new nuclear plants.[59]

III. Military Nuclear Power

The U.S. military has a long history of using small nuclear reactors, both in the Naval Nuclear Propulsion Program as well as in the Army's lesser-known Nuclear Power Program. Both programs began in the early 1950s as an outgrowth of the military's nuclear weapons research, but while the Navy's program since expanded and continues to play a major role in Navy acquisitions, the Army's program fell victim to post-Vietnam spending cuts and the declining popularity of nuclear power of the 1970s.

The Navy's Nuclear Propulsion Program began in 1948, with the first nuclear vessel being launched in 1954.[60] Enabling vessels to stay at sea without needing to return to port to refuel represented a major strategic advantage in the Cold War.[61] Submarines, which were previously required to resurface regularly in order to run diesel engines to charge their batteries, became much more capable and difficult to detect when nuclear reactors enabled them to operate continuously for months without resurfacing or refueling.[62] Aircraft carriers benefitted from nuclear reactors because the reactors reduced the vast amounts of fuel they needed to carry as well as the high speeds that nuclear propulsion could deliver—extremely helpful for launching and recovering aircraft.[63] As a consequence of these advantages, nuclear power quickly took on a prominent role in the Navy's Cold War missions, a role that became even more important with the advent of submarine-based nuclear missiles and the strategic need to counter the Soviet Union's parallel nuclear submarine fleet.[64]

The development of nuclear reactors for the Navy directly benefitted the burgeoning commercial nuclear power industry by providing much of the initial development costs and infrastructure for building commercial reactors.[65] In 1957, a joint public-private partnership between Westinghouse and the Naval Reactors Branch built the first U.S. commercial reactor, the Shippingport Atomic Power Station near Pittsburgh.[66] The Shippingport plant was envisioned by the head of Naval Nuclear Propulsion, Admiral Hyman Rickover, to both provide a test case for commercial nuclear power while also serving as a prototype for a naval reactor.[67] In addition to the Navy providing the industry with early research and design and building up the production capacity of reactor manufacturers, the Navy's nuclear schools have long since provided the industry with highly trained technicians who move on to civilian jobs after completing their military careers.[68]

The Army created the Nuclear Power Program in the 1950s to provide electricity at remote military installations; the Army Corps of Engineers ran the program in close cooperation with the civilian Atomic Energy Commission (the precursor to the DOE).[69] Similar to the Navy's used of small reactors scaled to an individual ship's power requirements, the Army used small reactors scaled to the needs of a single installation.[70] In addition to a training reactor in Fort Belvoir, Virginia, the Army used small reactors at bases in Wyoming, Idaho, Alaska, the Panama Canal Zone (utilizing a floating reactor barge), and even had a reactor based in McMurdo Station in Antarctica.[71] The program suffered an early setback after a major accident at an experimental reactor in Idaho in 1961,[72] but the program contin-

56. 42 U.S.C. §§ 16011–16042, 16271–16277 (2012).
57. *Energy Department Announces New Funding Opportunity for Innovative Small Modular Reactors*, U.S. Dep't Energy (Mar. 11, 2013), energy.gov/articles/energy-department-announces-new-funding-opportunity-innovative-small-modular-reactors; *cf.* Bryce, *supra* note 4 (discussing various SMR designs that companies have created).
58. Russell, *supra* note 55; Press Release, Babcock & Wilcox, B&W, DOE Sign Cooperative Agreement for Small Modular Reactor Funding (Apr. 15, 2013), http://www.babcock.com/news-room/Pages/BW,-DOE-Sign-Cooperative-Agreement-for-Small-Modular-Reactor-Funding.aspx.
59. Howland, *supra* note 19 ("In 2008, DOE offered $18.5 billion in nuclear plant loan guarantees and received [seventeen] applications. After several delays, earlier this year, DOE provided $6.5 billion and conditionally approved another $1.8 billion in loan guarantees for the [2200]-megawatt Vogtle nuclear plant in Georgia.").
60. Ronald O'Rourke, Cong. Research Serv., RL33946, Navy Nuclear-Powered Surface Ships: Background, Issues, and Options for Congress 2–3 (2010).
61. *See id.* at 2; *see also* Michael Sullivan, *Run Silent: The Birth of a Nuclear Navy*, Military.com (last visited May 25, 2016), http://www.military.com/Content/MoreContent1/?file=cw_f_runsilent.
62. O'Rourke, *supra* note 60, at 2.
63. *Id.*
64. Owen R. Cote Jr., *The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle With Soviet Submarines*, America's Navy 19 (2000), www.coldwar.org/text_files/newportpaper16.pdf.
65. Willis L. Shirk Jr., *"Atoms for Peace" in Pennsylvania*, Pa. Heritage Mag., Spring 2009, http://www.phmc.state.pa.us/portal/communities/pa-heritage/atoms-for-peace-pennsylvania.html.
66. *Id.*
67. *Id.*
68. *See* Kristi E. Swartz, *Nuclear Industry Looks to Navy to Fill Worker Shortage*, Atlanta J. & Const. (Aug. 24, 2012, 8:51 AM), http://www.ajc.com/news/business/nuclear-industry-looks-to-navy-to-fill-worker-shor/nRMQ9 (noting that commercial nuclear industry hiring Navy nuclear technicians has been a longstanding practice, and that a 2012 agreement between the Navy and commercial nuclear industry group has formalized this through a workforce transition program).
69. Robert A. Pfeffer & William A. Macon Jr., *Nuclear Power: An Option for the Army's Future*, Army Logistician, Sept.–Oct. 2001, at 4, 6.
70. *Id.*
71. *Id.*
72. Three technicians died in what has been the only fatal accident at a U.S. reactor. While the technicians attempted to perform routine maintenance, one technician removed a control rod, causing the reactor to instantly go critical

ued with improved safety measures and little controversy until it was discontinued.[73]

Despite the growth and ongoing success of the Navy's nuclear efforts, the Army's program never grew to the same extent.[74] Whereas nuclear power enabled ships to conduct lengthier deployments far from U.S. bases and allowed submarines to operate stealthily without the need to regularly resurface, the advantages of small land-based reactors for the Army were by contrast limited in scale and primarily logistical; thus, they never attained the same level of strategic importance to the military. The Army Nuclear Power Program fell victim to several pressures before it was discontinued in 1979.[75] Budgetary pressures on military spending after the Vietnam War led to heavy scrutiny of non-essential programs.[76] The low cost of fossil fuels at the time and a lack of awareness of the environmental impact of carbon emissions similarly lessened the economic and environmental incentives for retaining the program.[77] Finally, policy makers were growing pessimistic about nuclear power more generally after the Three Mile Island incident, and increasing concerns over safety and the cost of decommissioning plants and storing radioactive waste.[78]

IV. The Military's Current Reliance on Fossil Fuels and the Civilian Power Grid

Many of the circumstances that led to the Army Nuclear Power Program's demise have since changed. As the electricity consumption of the modern military grew, the price of oil greatly increased and the military has increasingly found itself operating for extended periods of time in countries without reliable local power and where regular supply lines are difficult or dangerous to maintain.[79] Given the disruptive nature of modern warfare—where a regime's existing energy infrastructure, if any, may be targeted by the United States or opposing forces for tactical reasons—it is reasonable to assume that future conflict zones will at best continue to present the military with extremely limited and unreliable local energy infrastructure.

The wars in Iraq and Afghanistan demonstrated the liability of relying on frequent shipments of fuel to keep major installations supplied with power.[80] A great deal of the wars' costs became the expense of importing and securely transporting diesel fuel to bases. The DoD estimated that the cost of a single gallon of gasoline could reach as high as $400 when supplying remote areas in Afghanistan.[81] The human toll, meanwhile, proved to be much greater; a 2010 study estimated that one in every twenty-four fuel convoys resulted in a casualty.[82] While fortified U.S. bases easily resisted attacks from insurgents (who typically lacked heavy weapons), the fuel convoys necessary to keep these bases running were far more vulnerable as they passed through contested territory.[83] These convoys presented insurgents with a comparatively easier target and roadside improvised explosive devices ("IEDs") quickly became the weapon of choice for attacking U.S. forces.[84] Thus, in addition to the financial and human costs of relying on a long, continuous supply line, the military was forced to divert troops and resources away from other wartime operations to safeguard its fuel convoys.[85]

Outside warzones, the U.S. military has continued to rely on fossil fuel shipments to power remote bases.[86] The carbon intensity of transporting diesel fuel by ship to power generators is considerable and, while efforts have been made to adopt more renewables on such bases, imported diesel often remains the primary source of power. Hawaii, home to several major military installations, relies heavily on imported oil to fuel its power plants and has electricity prices more than double the national average (and well above the projected cost of SMR).[87] Although the military is only responsible for less than one percent of carbon emissions in the United States, it is the largest source of carbon emissions in the federal government.[88] While justified to an extent by military necessity—particularly for conventionally-powered vessels,

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and trigger a steam explosion. SL-1 Report Task Force, U.S. Atomic Energy Comm'n, IDO-19302, IDO Report on the Nuclear Incident at the SL-1 Reactor (1961). This accident provided the basis for many modern safety features now required in commercial reactors. Susan M. Stacy, Proving the Principle 153–54 (2000).

73. *Id.* at 155.

74. *See generally* Pfeffer & Macon, *supra* note 69.

75. *Id.* at 4–5.

76. *Id.* at 5.

77. *Id.*

78. The 1979 Three Mile Island incident, caused by a combination of cooling equipment failure and operator error, resulted in the venting of radioactive steam after one of the plant's reactors experienced a partial meltdown. Although no deaths were attributed to the accident, it sparked a major shift in public opinion against nuclear power and led to a heightened regulatory focus on improving reactor safety. Bentley Mitchell, *Diffusing the Problem: How Adopting a Policy to Safely Store America's Nuclear Waste May Help Combat Climate Change*, 28 J. Land Resources & Envtl. L. 375, 378–79 (2008).

79. *See* Rebecca Smith, *Hacker, Terrorist Threats Spur Bases to Build Power Grids: Military Worries About Facilities Being Linked to Vulnerable Utility Companies*, Wall St. J., http://www.wsj.com/articles/hacker-terrorist-threats-spur-bases-to-build-power-grids-1413920177 (last updated Oct. 21, 2014) (noting that the military has become far more reliant on energy-intensive communications and technology in the last two decades at both domestic installations and on the battlefield).

80. Steven M. Anderson, *Save Energy, Save Our Troops*, N.Y. Times, Jan. 13, 2011, at A29 (estimating that the military spent twenty-four billion a year to keep bases in Iraq and Afghanistan supplied with fuel).

81. Nathan Hodge, *U.S.'s Afghan Headache: $400-a-Gallon Gasoline*, Wall St. J., Dec. 6, 2011, http://www.wsj.com/articles/SB10001424052970204903804577080613427403928.

82. Anderson, *supra* note 80.

83. *Id.*

84. *Id.* ("Some soldiers jokingly call the fuel trucks 'Taliban targets,' and for good reason—they are a high-payoff quarry for insurgents using nothing but homemade bombs.").

85. *Id.* (noting that "fewer fuel shipments would allow NATO to take highly trained troops off convoy duty and use them in combat or, even better, send them home").

86. King et al., *supra* note 15, at 27.

87. Aside from the obvious carbon footprint issues created by transporting oil across long distances to fuel power plants, the 20.8 cents per kilowatt-hour cost in 2012 was more than double the national average. William J. Barattino, ANS Nuclear Cafe (Jan. 23, 2012), www.ansnuclearcafe.org/2012/01/23/small-modular-reactors-on-military-installations.

88. The Assistant Secretary of Defense for Operational Energy Plans and Programs, Sharon Burke, estimated that in 2011 the DoD spent $20 billion on energy and consumed approximately five billion gallons of petroleum. Amaani Lyle, *DOD Must Have Petroleum Fuel Alternatives, Official Says*, Armed Forces Press Serv. (July 11, 2012), http://archive.defense.gov/news/newsarticle.aspx?id=117084.

ground transportation, and aviation—this fact undercuts the environmental goals of recent U.S. administrations and contrasts with the increased restrictions on emissions that have been placed on civilian power generation.

Outside of remotely located installations, an additional issue is reliability for installations that draw power from the grid in the United States.[89] The 2000–2001 electricity crisis in California, where a variety of factors contributed to serious energy shortages and price hikes, demonstrated that the civilian electricity market can be dangerously prone to brownouts and curtailment during times of high demand, limited supply, or when transmission lines are interrupted.[90] The increasing reliance on intermittent power sources like wind and solar have exacerbated these trends.[91] The growing capabilities of foreign entities to hack into the civilian electrical grid and the vulnerability of the existing transmission system to terrorist attack represent particular concerns for the military outside of the normal reliability challenges facing the civilian grid.[92] Military installations can cope with short-term outages, utilize back-up generators, or reduce power consumption during an energy crisis to a degree, but this dependency on unreliable local power grids represents a major strategic vulnerability in the long-term.[93] This vulnerability is particularly significant given the important role that the military could potentially be expected to play in responding to a domestic terrorist attack, natural disaster, or other crisis that could involve a disruption of the civilian electric grid.

V. A Mutually Beneficial Proposal: Joint Military-Commercial Development of Small Modular Reactors for Installations

There are two distinct problems that the proposal outlined in this Note will attempt to address: first, the failure of current incentives to encourage the commercial adoption of small modular reactors; and second, the high human, financial, environmental, and strategic costs of the military's continued reliance on both imported fossil fuels and unreliable civilian power grids to satisfy its energy needs. Appropriations for a program to design and build small modular reactors on military installations combined with legislation to help facilitate parallel commercial SMR development could help to solve both of these problems. Joint development efforts would reduce costs for both commercial and military operators and would lessen the risk of "lock-in"—where commercial industry might design a successful SMR design in isolation that would lack design considerations important for military applications.[94]

Authorizing funding for an SMR acquisition program in the annual National Defense Authorization Act would help launch a project of this scale.[95] Additionally, this authorization should combine the development of military SMRs with existing commercial SMR licensing efforts in order to directly aid the DOE's goal of promoting commercial adoption of SMR. An SMR design tailor-made for military use that bypassed the NRC design certification process could satisfy the military's needs, but it would create a reactor—like the small reactors in use with the Navy—that could not be readily adopted by commercial utilities.[96]

While waiving the military's design certification exemption would help translate to benefits to commercial industry, the military would not need to extend this further to waive its exemption from the COL requirement. Requiring the military to secure a commercial COL would neither benefit the military nor the industry, as it would seriously delay or block the implementation of SMR plants. A full waiver would limit the beneficial role the military could play in bringing down costs and testing out the reactors, while the commercial industry and the NRC make progress on longer-term licensing issues. A military program would still need to address site-specific concerns, but this could be done in consultation with the NRC—rather than NRC licensing—as it is currently done for other defense-related nuclear activities.[97]

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89. *See* Smith, *supra* note 79 (noting that military installation commanders are increasingly wary of civilian grid reliability and vulnerability issues).
90. *See* Timothy P. Duane, *Regulation's Rationale: Learning From the California Energy Crisis*, 19 Yale J. on Reg. 471, 514 (2002) (market manipulation, high temperatures and a lack of generating capacity all contributed to the crisis); *see also* Smith, *supra* note 79 (describing increased concerns by San Diego military authorities about their reliance on the local grid following the crisis).
91. Edward A. Reid Jr., *Renewable Energy: Growing Pains, Halting Gains*, Pub. Util. Fort., Nov. 1, 2004, at 60, 66.
92. Paul W. Parfomak, Cong. Research Serv., R43604, Physical Security of the U.S. Power Grid: High-Voltage Transformer Substations 2 (2014) (finding significant security vulnerabilities in U.S. civilian power grid, particularly in high voltage transformers at power substations); Rob Margetta, *NSA Chief Predicts "Dramatic" Cyberattacks on Grid*, CQ Roll Call (Nov. 21, 2014), 2014 WL 6520296 (Admiral Michael Rogers noted that China and one or two other powers likely have the ability to shut down the U.S. power grid).
93. *See* Smith, *supra* note 79 (noting a widespread sentiment amongst defense experts and installation commanders that existing back-up diesel generators were insufficient to compensate for weaknesses in relying on the civilian grid).
94. The military's choice of light water-cooled reactors for submarines locked the commercial nuclear industry into light water reactors (even though many have since recognized that alternative designs may have been more appropriate for commercial nuclear power). The military could risk either off-the-shelf commercial technology that does not completely address its needs or be forced to design new reactors from the ground up at great expense in the future if it does not actively participate in SMR development and later decides to adopt them. Andres & Breetz, *supra* note 16, at 8–9.
95. While the military services and DOE retain some discretionary funding, heightened scrutiny over defense budgets and current spending caps would require any spending program on the scale of funding an SMR acquisition program to receive congressional authorization. *See* Jonathan Weisman, *Senate Republicans Rebuff House Colleagues With Their Budget Plan*, N.Y. Times, Mar. 18, 2015, http://www.nytimes.com/2015/03/19/us/senate-budget-rejects-house-bid-to-skirt-military-spending-caps.html?_r=0.
96. A mobile reactor intended for service at a frontline base in a warzone would, however, likely require design considerations for mobility and combat survival that would not readily translate to commercial reactors. Telephone Interview with Brian Harris, *supra* note 13; *see* Andres & Breetz, *supra* note 16, at 7 (describing unique challenges that would be faced by front line reactors).
97. A potential issue, however, would arise if a military SMR plant planned to sell its excess power into the civilian market—the NRC retains jurisdiction over all commercial nuclear power plants, including those run by federal agencies, and would likely require a military SMR plant involved in commercial sales to meet the same requirements. 10 C.F.R. § 100 (2015). It may be advantageous to pursue additional NRC licenses, but it may also be more cost-effective to avoid the time and expense associated with these additional licenses. King et al., *supra* note 15, at 33 (noting that the NRC would only assert jurisdiction over military reactors if they were used for commercial power, but also suggesting that the military could potentially argue that such activities fall within its broad exemption for "mission critical" facilities).

Section 2513 of title 50 of the U.S. Code currently prohibits military and defense-related nuclear activities from expending money on the NRC licensing process:

> None of the funds authorized to be appropriated by the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1981 . . . or any other Act may be used for any purpose related to licensing of any defense activity or facility of the Department of Energy by the Nuclear Regulatory Commission.[98]

Amending this statute to specifically exempt a military SMR program from this prohibition would be a major first step in creating a new regulatory framework that would support the development of an NRC-certified reactor design for a military program. This could be accomplished by expressly exempting the SMR program from the prohibitions in § 2513.

A further necessary step is to amend the Atomic Energy Act to narrowly expand the NRC's jurisdiction over the design certification licensing of the proposed military SMR program. Section 2121(a) of title 42 of the U.S. Code places several nuclear activities wholly under the DOE's jurisdiction:

> The Commission is authorized to—
>
> (1) conduct experiments and do research and development work in the military application of atomic energy; . . .
>
> (3) provide for safe storage, processing, transportation, and disposal of hazardous waste (including radioactive waste) resulting from nuclear materials production, weapons production and surveillance programs, and naval nuclear propulsion programs. . . .[99]

To accomplish this, an additional clause could be added to § 2121 requiring that the proposed military SMR program, while previously exempt from any NRC regulatory or licensing requirements as a defense-related activity, must seek design certification for any reactor designs developed or purchased. The language of this clause would need to be clear in limiting the expansion of NRC jurisdiction to the design certification process, and specifically note that the SMR program retained its defense-related exemption for all other NRC licensing requirements.

Organizationally, recreating the Army Nuclear Power Program from scratch would not be cost-effective and would create unnecessary delays in addition to the delays already inherent in nuclear licensing and construction.[100] The best option for a renewed program is to have DOE, which already has experience operating similarly scaled experimental reactors for research and defense purposes, direct the design and operation of SMR plants.[101] An expansion of the Navy's existing nuclear program, which has established training facilities and doctrines, could provide military operators for any role where DOE personnel would not be appropriate.[102] DOE has a long history of working with DoD on sensitive nuclear projects as well as promoting the development of commercial nuclear technology, making it ideally situated to manage a program that has implications for both military and civil applications.[103] Additionally, while appropriations are necessary to fund a military SMR program, the same statutory language that authorized the original Army Nuclear Power Program remains in place and doesn't require any revisions for a new DOE-run military SMR program.[104]

VI. Military Benefits of Adopting Small Modular Reactors

While military adoption of SMR would have benefits for the commercial nuclear industry and further civilian energy goals, it would significantly address some of the serious energy security challenges that the U.S. military has faced as a result of its current energy practices.[105] Simultaneously, the military has increased its reliance on electricity for myriad purposes, while the power sources it has traditionally relied on have grown unsustainably expensive and subject to price volatility.[106] The vast majority of bases have power needs within 10–100 MW, making them well suited for the capabilities of SMR technology.[107]

A small nuclear reactor could provide a clean, dependable source of power to remote installations. The 2011 SMR feasibility study commissioned by DoD found that while nuclear power would be slightly more expensive than coal or natural gas in most domestic markets, it would likely prove more competitive in remote locations where fuel must be regularly imported.[108] While traditional large-scale reactors produce far more power than a remote Navy or Army base would require, SMRs can be scaled to meet the needs of a base and provide base load to augment the existing renewable power projects being employed by the military.[109] In reducing the

98. 50 U.S.C. § 2513 (2012).
99. 42 U.S.C. § 2121(a).
100. *See* King et al., *supra* note 15, at 49–50.
101. *See id.*
102. This would require some cultural and technical changes to the Navy's current maritime-focused nuclear field. Telephone Interview with Brian Harris, *supra* note 13.
103. *See generally* Hewlett & Holl, *supra* note 25.
104. 42 U.S.C. § 2121(b)(2) ("The President from time to time may direct the Commission . . . to authorize the Department of Defense to manufacture, produce, or acquire any atomic weapon or utilization facility for military purposes.").
105. Smith, *supra* note 79.
106. *Id.*; *see also* Ryan Koronowski, *Why the U.S. Military Is Pursuing Energy Efficiency, Renewables, and Net-Zero Energy Initiatives*, Climate Progress (Apr. 4, 2013, 2:34 PM), http://thinkprogress.org/climate/2013/04/04/1749741/why-the-us-military-is-pursuing-energy-efficiency-renewables-and-net-zero-energy-initiatives.
107. King et al., *supra* note 15, at 57–62.
108. Although electricity prices have since declined in many areas due to low natural gas prices, the 2011 CNA feasibility study found that without "first of a kind" expenses included,

> the cost of electricity from a small nuclear power plant would be about $0.08 per kWh, which is slightly higher than the projected average retail price of electricity for industrial users throughout the country. This price is substantially lower than electricity prices in some remote regions where military bases are located.

King et al., *supra* note 15, at 15–16.
109. A 160 MW reactor could meet the power needs of even the largest military bases. King et al., *supra* note 15, at 14. Base load plants are used to continuously provide the minimum power load needed by a system,

reliance on imported energy supplies, installations would also be less vulnerable to potential disruptions in supply by a foreign adversary or natural disaster.

In a warzone like Iraq or Afghanistan, SMR would mean that fuel convoys (and the expense and danger associated with them) could be greatly reduced with a portable SMR being flown in at the beginning of a conflict and removed when forces are withdrawn.[110] There are obvious safety concerns with transporting nuclear materials and safeguarding them in foreign warzones, but it should be noted that the U.S. military has routinely transported nuclear weapons on aircraft, nuclear reactors aboard ships visiting domestic and foreign ports, and protected myriad dangerous materials from attacks.[111] As with placing nuclear reactors aboard combatant ships like aircraft carriers or submarines, the tactical advantages of not being reliant on fuel resupply would outweigh the dangers of possible attacks.

The smallest outposts in a combat zone likely would not have great enough energy demand or sufficient personnel to make hosting a reactor practical while aircraft and ground vehicles would still require fuels apart from any SMR-generated electricity.[112] Any adoption of SMR, including semi-portable reactors suitable for quickly providing power in warzone bases, would thus not completely eliminate the need for imported fuels.[113] Those shipments could be greatly reduced, however, if they were no longer required for electric generation at the largest bases.

The Navy is currently conducting research on using nuclear power to break down water into hydrogen fuels (which can be used to fuel modified aircraft, generators, smaller vessels, and ground vehicles) in order to reduce or eliminate completely the vast amounts of aviation fuel aircraft carriers currently must carry.[114] The availability of SMR could provide the amount of energy necessary to turn local water supplies into liquid fuel useable to resupply smaller bases and transportation needs since imported fuel and renewable power sources are not able to efficiently carry out this energy-intensive process.[115] While the Navy's research is still in the early stages, the Army has been aware of the logistical possibilities of this process for some time, which could allow a forward-deployed base to create transportation fuel from local water supplies.[116] Although this technology is still in an early experimental phase, having an established SMR program in place could facilitate its quick adoption to meet transportation fuel needs in the future. Additional possible applications for SMR include saltwater desalination and heat co-generation, which could provide clean water and heating to remote bases.[117]

Despite the inherent safety of SMR and the fact that similarly scaled naval reactors enter ports around the world on a regular basis, there would likely be a local backlash against any attempts to install permanent, land-based reactors, particularly for U.S. bases on foreign soil.[118] Past revelations that the U.S. military had improperly stored hazardous materials and ignored local environmental laws led to criticism from political leaders in host countries and increased scrutiny over activities on foreign bases.[119] For this reason, the first installations to host SMR reactors should be domestic bases located in remote regions with limited or expensive access to power that could strongly benefit from their addition.[120] This was the type of installation that the Army Nuclear Power Program had focused on before it was discontinued.[121] An established record of safe operation at such bases would pave the way for wider adoption at less remote installations in areas with reliability concerns, while also providing an observable SMR example for both utilities interested in pursuing commercial SMR and advocacy groups concerned over the safety of a proposed SMR project.

VII. Commercial Benefits to Military Adoption of SMR

A military SMR program would primarily benefit the military, but the military's adoption of the technology would also result in major incidental benefits for the struggling commercial nuclear industry. These benefits, in themselves, can further the broader national strategic goals of limiting the United States' reliance on foreign fuel, reducing greenhouse gas emissions, and competing with foreign

augmenting more intermittent sources. *See Glossary*, U.S. Energy Info. Admin., https://www.eia.gov/tools/glossary/index.cfm?id=B (last visited May 29, 2016); *see also Electric Generators' Roles Vary Due to Daily and Seasonal Variation in Demand*, U.S. Energy Info. Admin. (Jun. 8, 2011), https://www.eia.gov/todayinenergy/detail.cfm?id=1710.

110. Fuel for bases represented a significant part of resupply convoys in Iraq. *See* Telephone Interview with Phillip Hokenson, former Field Artillery Battery Exec. Officer, U.S. Army (Feb. 17, 2015).

111. *See* Ctr. for Def. Info., *U.S. Nuclear Weapons Accidents: Danger in Our Midst*, 10 Def. Monitor, No. 1, 1981, at 1, 1–12 (discussing that nuclear weapons are located at hundreds of places throughout the U.S. and in foreign countries and are transported frequently from place to place).

112. *See* Andres & Breetz, *supra* note 16, at 4 (noting that reactors could easily meet larger forward operating bases' electricity needs and, absent hydrogen fuel technology advances, transportation would still require imported fuel).

113. Telephone Interview with Brian Harris, *supra* note 13.

114. Douglas Ernst, *U.S. Navy to Turn Seawater Into Jet Fuel*, Wash. Times (Apr. 10, 2014), http://www.washingtontimes.com/news/2014/apr/10/game-changer-us-navy-can-now-turn-seawater-jet-fuel.

115. *Id.*

116. Pfeffer & Macon, *supra* note 69, at 5–7.

117. Alexey Lokhov et al., OECD/NEA Study on the Economics and Market of Small Modular Reactors, Int'l Atomic Energy Agency (2013), www.iaea.org/INPRO/6th_Dialogue_Forum/session-4/2.sozoniuk.pdf.

118. Germany and Japan, two countries which host a large number of U.S. bases, have backed off of nuclear in the face of public opposition and concerns over safety. While Germany hopes to eliminate nuclear power entirely, Japan has backtracked from a similar plan after recognizing the economic necessity of nuclear. *See* Shihoko Goto, *Japan and Germany: Two Sides of Nuclear Reality*, Globalist (Oct. 24, 2013), http://www.theglobalist.com/japan-germany-two-sides-nuclear-reality.

119. John M. Broder, *U.S. Military Leaves Toxic Trail Overseas*, L.A. Times, June 18, 1990, http://articles.latimes.com/1990-06-18/news/mn-96_1_overseas-military-bases (noting that the United States was widely criticized by German politicians when Cold War hazardous waste contamination of German bases was revealed).

120. As a side note, it may be possible to sell excess power to surrounding communities, which could offset some of this opposition in remote regions with high electricity costs (this would, however, likely require NRC and Federal Energy Regulatory Commission oversight and involve additional regulatory requirements that may not be desirable). Telephone Interview with Brian Harris, *supra* note 13.

121. Pfeffer & Macon, *supra* note 69, at 6.

rivals in a potentially lucrative area of trade.[122] The military has frequently played a major role in developing complex defense-related technologies that have later been successfully commercialized for civilian use by U.S. companies; examples of this effect include commercial aviation, the early nuclear industry, computers, the internet, and GPS, among others.[123] Military involvement in the research and development of a particular technology can remove a great deal of the investor uncertainty and risk in undertaking such efforts independently, particularly where, as here, manufacturers do not have a guaranteed commercial customer to recover their costs.[124] DOE is already spending a great deal of money in grants and loan guarantees to assuage this risk, but the money could be better spent if the federal government served as a reliable first customer for SMRs rather than having manufacturers pursue SMR designs for a market that may or may not materialize.[125]

A large part of SMR's promise of affordability is that, with reactors being built in a single location according to a pre-certified design, they can be used to achieve much higher economies of scale than traditional reactors (which must be slowly and expensively assembled almost entirely on-site).[126] In order to reduce these construction costs, however, the manufacturer needs to be able to sell enough reactors to distribute the initial costs of the manufacturing facilities and to maintain its manufacturing capabilities and workforce over time.[127] As a well-funded repeat customer with needs that are independent of the market risks faced by commercial energy investors, the military could quickly order enough plants to help spread the production costs across multiple reactors, lowering the costs for future commercial purchasers, as well as future military acquisitions.[128] The military would also provide an important test case to demonstrate the safety, security, and operating costs of SMR technology.[129]

As with the Navy's nuclear program, an expanded land-based military reactor program would produce an additional benefit in creating a regular pipeline of trained nuclear technicians transitioning out of the military who could provide the commercial industry with an established source of technicians.[130] These technicians would be particularly useful as they would already be familiar with an NRC-certified SMR design similar, if not identical, to the reactors they would subsequently encounter in the commercial sector.[131]

VIII. Final Concerns

Since military adoption of SMR was first suggested, there has been criticism of the idea in particular, in addition to criticisms that are more broadly opposed to the expansion of nuclear power in general.[132] Despite the federal government's support for expanding nuclear programs, there remains broad opposition to any expansion or subsidy of nuclear power—though less opposition has been focused on military uses specifically.[133] In addition to criticism of the industry as a whole, SMRs have been specifically criticized for their economics and untested safety issues.[134] A 2008 law review article summarizes these issues in arguing why the government should stop subsidizing the industry: "Nuclear generators are prone to insolvable infrastructural, economic, social, and environmental problems. They face immense capital costs, rising uranium fuel prices, significant amounts of lifecycle greenhouse gas emissions, and irresolvable problems with reactor safety, waste storage, weapons proliferation, and vulnerability to attack."[135]

Vulnerability to attack is a significant area of concern, particularly for a mobile SMR plant at a frontline base during wartime, which might represent a major target for enemy attack. The military regularly safeguards hazardous materials and sensitive targets in warzones, including high explosives, aircraft, fuel depots, etc. Like a fuel depot or ammunition storage facility, a mobile SMR would need to be shielded from attack, but this would be easier to accomplish for a single stationary reactor than protecting regular fuel convoys.[136] Using Iraq as an example, a mobile SMR plant would likely not have been appropriate in the short period immediately surrounding the ground invasion (when the enemy's air force or heavy weapon capabilities were still intact), but rather would have been most practical during the years-long occupation and reconstruction process that followed, where

122. *See* King et al., *supra* note 15, at 4–6, 20, 27. Russia in particular has made great strides in developing SMR technology and aggressively marketing its designs abroad. *E.g.*, Eve Convent, *Russia's New Empire: Nuclear Power*, Pulitzer Ctr. on Crisis Reporting (Oct. 17, 2015), www.pulitzercenter.org/reporting/asia-europe-russia-empire-nuclear-power-reactor-generator-expo-sale-kremlin.
123. Linda D. Kozaryn, *All Benefit From DoD-Industrial Dual-Use Partnerships*, Am. Forces Press Serv. (May 17, 2000), http://archive.defense.gov/specials/outreachpublic/benefits.html.
124. *Id.*
125. *Small Modular Reactors*, *supra* note 7.
126. Solan et al., *supra* note 11, at 7.
127. *Id.*
128. The military could act as a "first mover" in absorbing initial development costs and encouraging risk-averse commercial operators to invest in SMR. Andres & Breetz, *supra* note 16, at 7–9.
129. Multiple operational plants with an established safety record would provide commercial SMR applicants with a much stronger case for the safety of a reactor design during the inevitable litigation challenges that would arise during the licensing process. *Id.*
130. *See* Swartz, *supra* note 68.
131. *Id.*
132. *See* Daniel Nexon, *Small Modular Reactors and US Military Bases*, Duck Minerva (Mar. 29, 2013), http://duckofminerva.com/2013/03/small-modular-reactors-and-us-military-bases.html (arguing that a military SMR would invite controversy on foreign bases, use unproven technology, and create unnecessary risk by transporting nuclear waste abroad, among other criticisms).
133. *Id.*
134. *See* Lyman, *supra* note 44, at 17 (arguing that there are serious unproven safety issues with operating multiple reactors on one site, that many of the advantages described by proponents are overly optimistic, and that the economics of producing less power would likely force SMR operators to seek to cut costs at the expense of safety and supervision in order to break even).
135. Benjamin K. Sovacool & Christopher Cooper, *Nuclear Nonsense: Why Nuclear Power Is No Answer to Climate Change and the World's Post-Kyoto Energy Challenges*, 33 Wm. & Mary Envtl. L. & Pol'y Rev. 1, 4 (2008).
136. Convoys must travel through unsecure territory and are particularly susceptible to improvised explosive device (IED) attacks. There is no limit on the size or destructive power of an IED's as they can be assembled by "daisy-chaining" numerous explosives together and burying them. Bases, however, could only be attacked by insurgents using rockets or mortars; these weapons were generally inaccurate and far less powerful than IED's (blast walls could effectively secure sensitive materials, like a reactor or ammunition dump, from rocket or mortar attack). Telephone Interview with Phillip Hokenson, *supra* note 110.

comparatively lightly-armed insurgent forces represented the primary threat.[137]

At permanent U.S. installations, the military already safeguards reactors—many naval bases have several active reactors in port at any given time—in addition to other dangerous materials (including nuclear weapons, ammunition dumps, conventional bomb stockpiles, etc.). Terrorist attacks are far more likely to be directed against "soft" personnel targets than fortified infrastructure protected by layers of security.[138] The threat should not be dismissed or taken lightly, but it must be seen as a remote and manageable risk in the context of the Navy's experience, where hundreds of nuclear reactors on highly visible ships have docked in domestic and foreign ports for the last sixty years without suffering a reactor incident from a terrorist attack or any other threat.[139]

Public perception of the dangers of nuclear power may be the most difficult challenge even if all of the technical and financial issues can be addressed.[140] Despite nuclear power's impressive safety record when compared with other forms of energy, society tends to overestimate the remote danger of a catastrophic accident while downplaying the more routine dangers of air pollution, water contamination, gas explosions, and mining deaths.[141] The impeccable safety record of the Navy's nuclear program could give more credibility to a military SMR program than a commercial operator.[142] If the Navy's experience is any indication, however, a rigorous safety reputation developed over time would likely be necessary for a land-based reactor program to gain the same level of societal acceptance as other methods of energy generation.[143] An effort by policy makers to emphasize an expanded military SMR program's national security benefits, rather than merely its role in cutting long-term federal energy costs or providing incidental benefits to the commercial market, could also offset some of these safety concerns.[144] Conversely, natural gas's risks may come under greater scrutiny and face heightened regulatory costs as natural gas becomes more central to U.S. energy—natural gas has suffered numerous fatal accidents in recent years from power plant and pipeline explosions, and some natural gas facilities and liquefied natural gas ("LNG") tankers in densely populated urban areas pose the risk of catastrophic fatalities in the event of an accident or terrorist attack.[145]

The inevitable waste created by any new nuclear activity is also a major area of concern. Due to the perceived risks of storing commercial spent nuclear fuel, there has been strong local opposition to proposed storage sites like Yucca Mountain.[146] While a long-term solution for storing nuclear waste remains a major obstacle for the commercial nuclear industry, defense-related nuclear projects are able to bypass this obstacle to a degree and secure their waste without going through the more politically difficult NRC process.[147] The most prominent example of this has been the Waste Isolation Pilot Plant ("WIPP") facility in New Mexico, which has become the primary long-term storage site for defense-related transuranic nuclear waste and, despite several recent safety incidents, remains popular with the local community.[148] WIPP's relative success as a long-term geologic depository provides a model for future defense nuclear waste storage projects.[149] Spent nuclear fuel from the Navy's nuclear reactors—the closest analogue to the waste that would result from a new military SMR program—is currently being stored at the DOE's Idaho National Laboratory.[150] The U.S. Secretary of Energy, Dr. Ernest Moniz, recently noted that while much of the defense nuclear waste remains in temporary storage at such sites across the country, the Obama Administration is pursuing a new, defense-only long-term geologic repository.[151] It is also important to note that the remote environmental risks posed by nuclear waste pale in comparison to the massive air pollution and waste materials generated by even "clean" coal.[152]

A final area of criticism is the economics behind any further subsidization of the nuclear industry, especially when industry proponents have often underestimated the costs of

137. *Id.*

138. A major trend among terrorist groups worldwide has been to attack soft targets with the possibility of causing large numbers of casualties, while avoiding "hard" targets protected by heavy security (which require large groups of operatives, complex planning, and a much greater risk of being stopped). Scott Stewart, *The Moscow Attack and Airport Security*, STRATFOR (Jan. 27, 2011, 5:54 AM), https://www.stratfor.com/weekly/20110126-moscow-attack-airport-security.

139. *See generally* James Conca, *America's Navy: the Unsung Heroes of Nuclear Energy*, Forbes (Oct. 28, 2014, 5:15 PM), http://www.forbes.com/sites/jamesconca/2014/10/28/americas-navy-the-unsung-heroes-of-nuclear-energy.

140. Telephone Interview with Brian Harris, *supra* note 13.

141. *See* Paul Slovic & Elke Weber, *Perception of Risk Posed by Extreme Events*, presented at Risk Management Strategies in an Uncertain World at 8 (New York, Apr. 12–13, 2002).

142. Conca, *supra* note 139 ("The Nuclear Navy has logged over [5400] reactor years of accident-free operations and travelled over 130 million miles on nuclear energy, enough to circle the earth [3200] times.").

143. *See* Slovic & Weber, *supra* note 141, at 8–9.

144. The fact that the public does not object to similarly-scaled shipboard nuclear reactors frequently transiting and docking near major coastal metropolitan areas demonstrates a greater willingness to accept nuclear power when it is visibly connected to national security. *See* Conca, *supra* note 139.

145. *See* John Gray, *Choosing the Nuclear Option: The Case for a Strong Regulatory Response to Encourage Nuclear Energy Development*, 41 Ariz. St. L.J. 315, 325 (2009) ("With natural gas tankers docking in highly-populated harbor cities like New York or Boston, the casualty count of such an attack could easily number in the thousands, if not millions.").

146. Montange, *supra* note 28, at 400 (discussing the controversy over Yucca Mountain and long-term storage of nuclear waste).

147. 42 U.S.C. § 2121(a)(3) (2012) (giving the DOE rather than the NRC jurisdiction over waste from defense-related nuclear activities).

148. Patrick Malone, *Repository's Future Uncertain, but New Mexico Town Still Believes*, Santa Fe New Mexican (Feb. 14, 2015, 8:00 PM), http://www.santafenewmexican.com/special_reports/from_lanl_to_leak/repository-s-future-uncertain-but-new-mexico-town-still-believes/article_38b0e57b-2d4e-5476-b3f5-0cfe81ce94cc.html.

149. *Id.* WIPP is not without its problems, but those problems are less serious than that of Yucca Mountain. Robert Alvarez, *The WIPP Problem, and What It Means for Defense Nuclear Waste Disposal*, Bull. Atomic Scientists (Mar. 23, 2014), http://www.thebulletin.org/wipp-problem-and-what-it-means-defense-nuclear-waste-disposal7002#.UzBYydcs1FA.twitter.

150. James D. Werner, Cong. Research Serv., R42513, U.S. Spent Nuclear Fuel Storage 11 (2012).

151. Ernest Moniz, Sec'y, U.S. Dep't of Energy, Remarks on "A Look Back on the Blue Ribbon Commission on America's Nuclear Future" at the Bipartisan Policy Center (Mar. 24, 2015), http://energy.gov/articles/secretary-monizs-remarks-look-back-blue-ribbon-commission-america-s-nuclear-future.

152. "[C]oal plants produce approximately three-fifths of U.S. sulfur dioxide emissions, one-third of mercury emissions, one-quarter of nitrogen oxide emissions, and one-third of carbon dioxide air emissions." Gray, *supra* note 145, at 322.

nuclear power.[153] Additionally, it may be difficult to justify an increase in defense spending—even if it were directed through the DOE—on a new and expensive acquisition program during a postwar period of budget cuts and difficult funding decisions. While certain aspects of SMR would be unavoidably expensive, particularly during the research & development and design certification stages, a military program would be able to avoid many of the biggest costs faced by commercial operators—foregoing the years-long COL process and the inevitable litigation that accompanies it and having reduced security costs by taking advantage of the heavy security measures and established protocols already in place on every major military installation in the post-9/11 era.

The costs of maintaining current energy supplies are, in the short term, likely much lower than developing and implementing an SMR program.[154] The economic benefits, however, come from what nuclear power can offer—energy security against what has been an extremely volatile oil and natural gas market and increasingly expensive regulations raising the cost of coal.[155] It is also important to note that, while the expense of a new military reactor program might be difficult to justify in the isolation of defense budgeting, it becomes a much more cost-effective proposition for wider U.S. government spending policy when seen in the context of the money already committed to commercial SMR development.[156]

IX. Conclusion

An authorization and appropriations program for DOE and the military to work with manufacturers in jointly developing and installing SMR power generation at military bases, combined with an amended § 2513 of title 50 of the U.S. Code and § 2121 of title 42 to require military SMR to attain NRC design certification, would help address several major challenges facing the military and the commercial nuclear industry. The U.S. military would be able to reduce its dependence on fossil fuels, long energy supply lines, and vulnerable civilian energy grids, while commercial industry would be able to take advantage of an innovative new technology without having to shoulder all of the risks and startup expenses that otherwise might prevent it from doing so.

The United States has a strong national interest in seeing SMR succeed apart from the health of the nuclear industry or the energy needs of the military. A faster and more widespread adoption of SMR would serve multiple purposes: alleviating the reliability impact of increasingly expensive coal plants being closed down, replacing aging nuclear power plants nearing decommissioning, adding critical base load to an increasing mix of renewable sources, making nuclear power an option in regions previously too small to support a traditional reactor, and displacing more carbon intensive coal and natural gas production in line with environmental goals.[157] Additional nuclear capacity could also help insulate the U.S. energy market from potentially devastating volatility in the natural gas sector.[158] The United States has already invested a great deal of money attempting to promote the adoption and furtherance of advanced nuclear technology, and Congress and successive presidential administrations have consistently supported measures to encourage SMR development.[159] This money would be more effective at encouraging commercial adoption, however, if the military was able to provide a test case for the technology and work with the private sector to facilitate its early development.

153. *See* Kristin Shrader-Frechette, *Climate Change, Nuclear Economics, and Conflicts of Interest*, 17 Sci. & Engineering Ethics 75, 75 (2011) (describing numerous examples of nuclear industry-sponsored studies which underestimate costs of nuclear projects to make them appear more competitive).

154. *See* Chediak, *supra* note 12 (describing the disruptive impact on nuclear economics of low natural gas prices).

155. Nuclear Energy Inst., Status and Outlook for Nuclear Energy in the United States 21 (2014) ("[Nuclear power plants] provide price stability and are not subject to the price volatility associated with gas-fired generating capacity, in particular.").

156. Howland, *supra* note 19.

157. Nuclear Energy Inst., *supra* note 155.

158. *Id.*

159. Howland, *supra* note 19; *but cf.* E-mail from Larry Brown, *supra* note 14 (noting that the actual amount committed to SMR thus far has fallen short of actual development costs and that most of the support has been in the form of loan guarantees which have not been used yet).