PERSPECTIVE

Small Modular Reactors: A Possible Path Forward for Nuclear Power

Nick Cunningham

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Introduction

Nuclear power generates 21% of total electricity generation in the United States.[1] Nuclear power has played a vital role in meeting the nation's energy supply and has provided baseload electricity for more than forty years.

America pioneered the nuclear industry. The U.S. military and national laboratories made nuclear power a reality during World War II, and worked with the private sector to spark a new commercial industry in the post-war period.[2]

To this day, the leading global nuclear energy companies have their origins in the successful partnership with the U.S. government to support nuclear power. America still leads the world in installed nuclear capacity with 104 reactors, representing about 30% of global nuclear generation.[3]

However, the U.S. is in danger of ceding leadership in nuclear power to other countries. The nuclear industry has experienced a 30-year drought in building new plants. Cost overruns, construction delays, inaction on handling nuclear waste, and low natural gas prices continue to be challenges for the industry.

The nuclear industry needs a new approach. Developing Small Modular Reactors (SMRs) offers a new path for the nuclear industry. SMRs are defined as reactors smaller than 300 megawatts, or about less than one-third the size of a conventional large reactor. By shifting from large nuclear plants to SMRs, the nuclear industry could solve several of the major problems that have long plagued nuclear power.

Why Should the U.S. Continue to Support Nuclear Power?

Global electricity demand is set to grow by an estimated 80% between 2010 and 2030.[4] To meet this massive demand for power, large investments in new power plants will need to be made.

Moreover, in the United States, the vast majority of the nation's nuclear power plants are nearing the end of their originally designed lifetimes. As of mid-2012, 73 of the 104 reactors have received 20-year license renewals to operate beyond their original 40-year permit.[5] Many more in the coming years will receive extensions as well. However, by the 2030s, unless a large effort is undertaken to build new reactors, most of these aging plants will need to be retired. America will need to somehow make up for one-fifth of the nation's power supply going offline.

Why should nuclear power be a part of the answer? There are several reasons.

First, as the only source of large baseload power that does not emit greenhouse gases or other air pollutants, nuclear power is critical in the fight to mitigate the worst effects of climate change. Renewable energy technologies will continue to grow, and nuclear fusion will power economies in the future, but there is no conceivable scenario in which the world meets its climate targets without conventional nuclear power.

Second, the U.S. has played a fundamental role in building the nuclear non-proliferation regime. Beginning with President Eisenhower and the "Atoms for Peace" plan, the U.S. has supported the peaceful use of nuclear power while preventing the spread of nuclear weapons. The Nuclear Regulatory Commission (NRC) is the leading licensing and regulatory body for nuclear industry worldwide, and it sets the standard for safety that other countries follow.

Not only does the U.S. "export" high safety standards in its reactor designs, but through 123 Agreements it requires rigorous non-proliferation measures as a requirement of doing business with American nuclear companies. With China expected to more than triple the number of installed nuclear reactors between 2011 and 2015, the U.S. may become less relevant in ensuring adequate safeguards against weapons proliferation. [6] A strong domestic nuclear industry will better position the U.S. to lead on this issue.

Third, nuclear power serves as a hedge against the price volatility of fossil fuels. While dramatic declines in wellhead prices for natural gas have led to it capturing an increasing share of the market in recent years, natural gas prices have historically been extremely volatile. Additionally, with the prospect of a price being levied on carbon-based fuels in the coming years, nuclear power can ensure cheap and reliable power for decades.

Finally, the rapid increase in demand for electricity around the world over the next several decades presents the U.S. with a huge opportunity to create jobs through exporting nuclear technology. Demand for nuclear power is expected to increase by 70% over the next 20 years, and America is well-positioned to capture much of that new business.[7]

The Nuclear Industry Has Stalled

A variety of factors have conspired in the last several decades to halt the advance of nuclear power. Many plants experienced construction delays and cost overruns in the 1970s and 1980s, forcing utilities to shift to alternatives. Concerns over safety have made siting extremely difficult. Public outcry over several infamous incidents – Three Mile Island, Chernobyl, and Fukushima – has forced societies around the globe to reconsider nuclear power.

Even when nuclear power makes financial sense for both ratepayers and utilities, the long-term payback for assets that have lifetimes of up to 60 years make investors nervous, driving up the cost of finance.

Despite these challenges, in recent years many believed a nuclear "renaissance" was afoot. Rising energy demand and concerns over climate change led to plans for new power plants. However, the renaissance came to an abrupt standstill due to the financial crisis and low natural gas prices, at least in the United States. A few projects are under construction, but the industry remains stalled.

The major problems that keep utilities from investing in new nuclear power plants can be addressed if the industry shifts towards Small Modular Reactors. There are many advantages of SMRs over conventional large reactors and they will be discussed below.

Advantages of Small Modular Reactors

Flexibility

There are several features of SMRs that provide greater flexibility relative to conventional large reactors.

First, SMRs can be added incrementally to load centers as demand increases. If electricity demand is increasing at a slow rate, a large nuclear reactor might greatly exceed the required load capacity, making it difficult to justify to ratepayers. Adding small reactors incrementally may better match supply with demand.

Second, once a reactor is constructed, additional reactors at the same site will be easier and cheaper to build. Once an initial reactor is approved, the regulatory process for obtaining permits for subsequent reactors would be less onerous.[8]

Third, utilities can site SMRs on the same sites as other power plants. The rapidly aging fleet of coal plants will result in a wave of retirements in the coming years, and coal plants can be swapped with SMRs to take advantage of the existing sites and connections to the grid.[9]

Fourth, SMRs can be used for a variety of energy applications that conventional large reactors cannot, such as desalination, industrial processes, hydrogen production, oil shale recovery, and district heating.[10] Such versatility allows for SMRs to meet energy needs for more than just large baseload power.

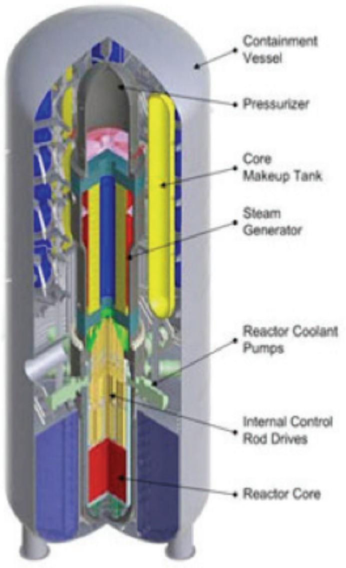
Fifth, multiple small reactors can also improve operating time, as a single site can have three or four SMRs, allowing one to go off-line for refueling while the other reactors stay online.[11] This allows power to be continuously generated, whereas in a conventional nuclear reactor, the entire plant must go offline to refuel.

Finally, SMRs can be built to be "grid-independent."[12] For military bases that want to avoid the vulnerability to the commercial electric power grid, SMRs can provide an off-grid solution. Also, in remote areas where it would not be cost-effective to build a larger nuclear power plant, or in places where the transmission grid is not well-developed (i.e. developing countries), SMRs can provide a source of baseload power.

Reduced Safety and Weapons Proliferation Concerns

SMRs can offer improved safety and security over conventional large reactors because of specific design features inherent to small reactors. First, one danger from nuclear power plants is the radiation from the reactor core. SMRs offer a reduction in danger from radiation because a smaller reactor core produces less radiation.[13]

Second, due to their small size, SMRs are better able to incorporate passive safety features – those that do not require human or electronic actions to function properly.[14] These include cooling systems that use gravity instead of relying on access to power, natural convection systems, and passive heat removal.[15] For example, in the event something goes wrong, Westinghouse's SMR is designed to keep the reactor cool for several days without the need for operators or power.[16] While the latest reactor designs are incorporating passive safety features, including for large reactors, passive safety features are inherently easier with small designs due to a smaller reactor core.



Westinghouse design for a SMR

Third, SMRs can benefit from a simplification of design, using less components, resulting in a more compact reactor.[17] SMR designs can eliminate the need for coolant pipes, which are considered the most significant safety challenge during the development of nuclear power plants.[18] An integral design, in which the primary reactor core, the steam generator, and the pressurizer are incorporated into a single common pressure vessel, is only possible in a small design.[19] In comparison, large reactors have components outside the containment vessel, increasing the chance of an accident.

Fourth, unlike large reactors, SMRs can be installed underground, reducing the vulnerability to a terrorist attack or natural disaster.[20] A design from Gen4, a nuclear reactor vendor, seals off the reactor underground. This allows for it to never be opened once it is installed, enhancing proliferation resistance.[21] It would also operate for 10 years before refueling would be needed, compared to conventional large reactors that require refueling every 18-24 months.[22]

Lower Upfront Costs

The greatest challenge facing the nuclear power industry is the upfront costs of new reactors. Although large reactors should be able to take advantage of economies of scale, there are economic advantages to small designs. Large reactors require substantial upfront investment, with long permitting and construction times before a return on investment can be realized.

These upfront costs make investing in a large nuclear power plant highly risky, even if the final cost per kilowatt-hour is profitable. A large nuclear power plant can cost between $6 and $9 billion, often exceeding the financing capabilities of most financial institutions, utilities, or even small countries.[23]

Conversely, small modular reactors at commercial scale could produce a 100 MW plant for $250 million.[24] Due to lower upfront costs and shorter lead times, SMRs would present lower financial risks, allowing for significantly lower costs of financing. The shorter lead times for SMRs allow for more certainty for investors, and the ability to change with market conditions.[25]

The smaller project size of each additional reactor also reduces the risks of cost-overruns.[26] This translates not only to lower absolute costs, but also lower upfront capital costs, making it easier for projects to attract financing, at better rates.[27]

Shorter construction times also provide a quicker revenue stream. SMRs can be built in roughly one-half to one-third of the time required for conventional plants.[28]

Even comparing multiple small reactors to the equivalent installed capacity of one large reactor, SMRs allow incremental capacity to come online while the large reactor is still under construction. SMRs create revenue generation immediately after each small unit is completed, and the owner can retire debt before the next increment is constructed.[29] Similarly, the SMR units can be under parallel construction (multiple reactors under construction simultaneously), allowing the full SMR project to be completed before the large nuclear reactor, a significant cost advantage for SMRs over large reactors.[30]

Another major drawback for conventional large reactors is the lack of standardization. This leads to long, expensive, and uncertain time periods for licensing and siting. SMRs can overcome this hurdle with standardized designs, standardized components, and enhanced safety from reduced reactor size, all of which are not easy to accomplish with large reactors.[31]

Small Modular Reactors, as their name suggests, can be "modularized". SMRs can be constructed in factories and actually shipped to site. Factory construction allows for greater quality control, predictability and scheduling. In contrast, large reactors are designed and built uniquely for each project, which can lead to delays and inflated costs. [32]

Major Challenges for SMRs

There are, however, several obstacles that are slowing the development of SMRs.

Institutional Obstacles

The most difficult challenge currently facing SMRs is the institutional barriers. Currently, the Nuclear Regulatory Commission has not certified a single SMR design. Despite the variety of SMR designs from several nuclear vendors, the NRC has lacked sufficient human and technical capacity to license small modular reactors in the past.[33] Even as policymakers have expressed greater interest in SMRs in recent years, the licensing process for a new design takes several years at a cost of hundreds of millions of dollars.[34]

Also, many regulations create a difficult environment for small reactors and favor large reactors. For example, the NRC requires 10 mile emergency planning zones around nuclear power plants, making it difficult to site a small reactor near urban centers where it could be used for energy applications other than centralized electricity generation.[35]

SMRs will need to overcome this long history of institutional bias towards large reactors. As the most prominent licensing body for the nuclear industry worldwide, the NRC to a certain degree, shapes the global future for nuclear power. If the NRC does not lead on small modular reactors, it may be an uphill battle for the SMR industry.

No Performance History

The nuclear industry has maintained a high performance standard with its fleet of large light water reactors, and SMRs would need to demonstrate the same high performance. However, as with any new technology, SMRs have no track record to prove their performance. The industry lacks a credible demonstration project that would inform future projects and inspire confidence.[36] SMRS need to demonstrate advantages over conventional plants, including advantages in cost, safety and flexibility.

Looking forward, this creates a “chicken and egg” problem. In order to bring costs down, nuclear vendors will need a high-tech manufacturing facility to mass produce small reactors. However, in order to justify the construction of such a facility, the industry estimates it will need to book dozens of orders upfront. It cannot book these orders without proof of cost, safety and performance. Industry leaders are hesitant to be the “first-mover” in an uncertain market, and governments are reluctant to provide incentives or invest in unproven products.

Safety Concerns

While there are real safety benefits of SMRs, critics site new safety concerns with SMRs that are not associated with conventional nuclear plants. The owner of small modular reactors would need to manage, inspect, and maintain more reactors for the same amount of power output as a single large reactor.[37] The industry needs to prove that the inherent safety benefits of SMRs over large reactors outweigh the downsides.

Nuclear Waste

Disposal of spent nuclear fuel has confounded the nuclear industry for decades and the problem of waste disposal will still need to be dealt with for SMRs. While large reactors suffer from the same problem, expanding the use of SMRs would mean waste from more reactor sites would need to be coordinated.[38] The quantity of waste may not change, but a given amount of waste is easier to manage from one site, rather than multiple.

The problem of disposing nuclear waste is a serious one, and the lack of a solution despite 30 years of debate is troubling. In January 2010, President Obama setup a Blue Ribbon Commission (BRC) to study the problem and to recommend actions to finally address the nuclear waste problem. The BRC recommended the establishment of a consent-based approach to siting a waste facility, the development of interim storage facilities, the creation of a separate government entity tasked only with addressing nuclear waste, as well as several other recommendations.[39] The recommendations will be difficult to pass through Congress, but until resolved, the nuclear waste problem will bedevil the entire nuclear industry, including SMRs.

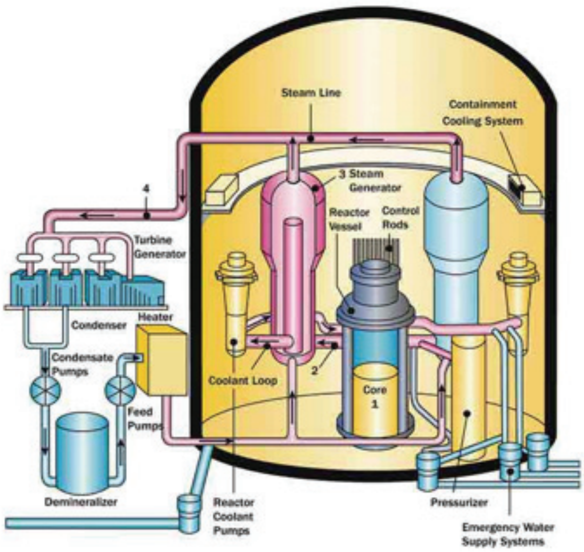
Low Natural Gas Prices

Another problem that is not unique to SMRs, but plagues the nuclear industry as a whole, is the current low prices of natural gas.

Due to major advances in hydraulic fracturing and horizontal drilling, the U.S. is awash in natural gas. Prices have plummeted, and the Energy Information Administration (EIA) estimates that prices will rise very slowly over the next two decades. For example, in their 2012 Annual Energy Outlook, the EIA predicts that natural gas prices will not rise back above $6 per million Btu until around 2030.[40] SMRs may need natural gas prices to reach $7 or $8 per million Btu to be competitive.[41]

This makes any new nuclear power plant, including an SMR, uneconomical compared to natural gas. Unless natural gas prices rise more quickly than expected, or Congress implements a price on carbon, nuclear power may struggle to compete.

Typical Pressurized-Water Reactor



Progress in Rolling Out SMRs

In recent years, the government has tried to provide incentives to kick-start the moribund nuclear industry. As part of the Energy Policy Act of 2005, loan guarantees and risk insurance were extended to new nuclear power plants.[42] However, although loan guarantees have provided enough support to help four new reactors move forward, these have proven to be the exception. Looking foward, it will be exceedingly difficult to build additional large nuclear power plants.

Policymakers have become increasingly interested in making SMRs a reality as an alternative to large plants. In January 2012, the Department of Energy announced a new initiative to support SMR development. DOE plans on spending $452 million over the next five years (subject to congressional appropriations) to help nuclear vendors through the design and licensing process.[43]

The program will provide 50% of the cost in the form of a grant while the industry would need to pay for the other half. DOE stated that it is looking for designs that can be licensed and up and running by 2022. Several companies have applied for the funding.

More Needs To Be Done

Several of the issues discussed above – difficult in licensing, unproven projects, and a “first-mover” problem – present a role for the government.

The NRC can work with nuclear vendors through the licensing process to reduce the time required for licenses to be issued. Reducing the time and cost for design licensing will accelerate the development of SMRs.

Also, the NRC and other agencies can devise ways to support the first wave of demonstration projects. For example, the Department of Defense, with its large procurement budget, can purchase SMRs for its military installations. Government entities can establish long-term power purchasing agreements (PPAs) to provide a minimum level of demand for SMRs. This will allow the industry to book early orders, prove the concept and bring down costs.

Finally, Congress can provide either supply side (tax incentives) or demand side (clean energy standards) to support the nascent SMR industry.

Conclusion

The U.S. has been a leader in nuclear power since its inception, but its position is slipping. National security concerns – climate change, nuclear non-proliferation, ensuring low-cost electricity, and leading in a critical export industry – justify a concerted effort to rebuild the strength of the nuclear industry.

However, the challenges currently facing the nuclear power are potentially insurmountable unless the industry and government work together to forge a new path. Moving swiftly to develop Small Modular Reactors offers a viable approach. SMRs offer the operational flexibility that large reactors do not. By design, SMRs can be inherently safer than large reactors. Perhaps most importantly, SMRs offer serious cost advantages over the larger plants.

The challenges facing SMRs are similar to those facing the nuclear industry as a whole. An active role for government is needed to help bring this new technology to market. The government has made a good first step in establishing a public-private partnership to make SMRs a reality, but more progress is needed.

Nick Cunningham is a Policy Analyst for Energy and Climate at the American Security Project

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Building a New American Arsenal

The American Security Project (ASP) is a nonpartisan initiative to educate the American public about the changing nature of national security in the 21st century.

Gone are the days when a nation's strength could be measured by bombers and battleships. Security in this new era requires a New American Arsenal harnessing all of America's strengths: the force of our diplomacy; the might of our military; the vigor of our economy; and the power of our ideals.

We believe that America must lead other nations in the pursuit of our common goals and shared security. We must confront international challenges with all the tools at our disposal. We must address emerging problems before they become security crises. And to do this, we must forge a new bipartisan consensus at home.

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ASP exists to promote that dialogue, to forge consensus, and to spur constructive action so that America meets the challenges to its security while seizing the opportunities the new century offers.

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