Investment in Alternative Applications for Next-Generation Nuclear Reactors in the United States

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Abstract

The United States government should incentivize alternative applications for next-generation nuclear reactors by creating a demonstration program for innovative concepts that extend beyond baseload power applications. While the US does have the Advanced Reactor Demonstration Project to support next-generation reactor systems, its primary objective is to support the commercialization of advanced reactors to be used for traditional power generation. Many next-generation reactors have unique features though that lend themselves to alternative applications like off-grid power generation, water desalination, and carbon capture. The US government should embrace these unique features and create pathways for companies to bring design concepts to demonstration and eventually commercialization. A demonstration project for alternative reactor applications could better help the US support fundamental research applications from innovation hubs like the Department of Energy’s ARPA-E program and tackle our carbon emissions goals.

The US government should incentivize applications for next-generation nuclear reactors that extend beyond traditional baseload power applications. The world’s energy demands are projected to increase over the next century thanks to trends like transportation electrification and mass adoption of advanced heat pump technology. To simultaneously supply the world’s energy requirements and meet international emissions goals, the US has to sustain and continue investing in clean sources of energy, like nuclear. While the US does have ongoing demonstration projects for advanced nuclear reactor systems, their main focuses are to bring new reactor designs to market that will ultimately support baseload power to the conventional electric grid. Advanced nuclear reactors have several unique qualities though, that present unique opportunities for non-traditional power applications. The US government should embrace these unique opportunities and offer pathways for companies to bring design concepts to demonstration and eventually commercialization.

There are already several proposed alternative applications for nuclear reactors. Some of them have been proven effective and are already in use around the world, like nuclear desalination of seawater. Others have only recently been proposed with advancements in smaller, more modular reactor designs. Investing in alternative applications for nuclear reactors might spur innovations that allow us tackle other grand challenges associated the 21st century, like providing clean drinking water, sustainably powering block chain technology, and making direct air capture of carbon feasible.
Microreactors, being able to be transported via shipping containers, present unique opportunities to power remote commercial/industrial operations. Cryptocurrency mining is one industry that might benefit from such a remote power source. Mining cryptocurrency currently consumes as much electricity as the entire country of Chile, with only 39% of its consumed electricity currently coming from renewable resources. It is often cited as a looming threat to climate change, and the energy-intensive block chain technology that it runs on continues to find new applications in today’s society. Some of the world’s largest cryptocurrency mining operations exist in Iceland, where miners can take advantage of the low temperatures to minimize cooling costs. Microreactors could enable similar cooling advantages by supporting remote operations in places like Alaska without adding carbon emissions to the atmosphere. At the same time, microreactors could lower costs of grid infrastructure development by essentially functioning as a large on-site diesel generator. The same concept could be applied to other operations that have high cooling costs, like large data centers.
Heat and Steam Sources

Many advanced reactor designs are high-temperature systems that make nuclear well-equipped to be used for desalination applications. Large light water reactors have already been proven as successful cogeneration sites that desalinate water at existing nuclear generating stations by diverting steam to a desalination system during non-peak generating hours. In recent years though, Korea has standardized a small modular react (SMR) designed specifically for cogeneration of potable water and has signed a pre-project engineering contract with Saudi Arabia to build one. Russia has also developed a series of floating nuclear power plants, some of which can be outfitted for desalination applications, and Argentina has expressed interest in using its CAREM-25 design for desalination. While US SMR designs, like those developed by NuScale and Westinghouse, are certainly capable of being outfitted as desalination cogeneration sites, there is no active push to bring such applications to demonstration.

Several next-generation reactor designs operate at very high temperatures and could prove useful for providing steam to district heating distribution systems. There are hundreds of district heating systems throughout the US that heat a wide range of facilities, like college campuses, hospitals, airports, military bases, and the downtown areas of cities like New York, Boston, San Francisco, and Denver. As it stands right now, more than 90% of all district heating systems in the US are powered by burning natural gas, oil, or coal. Microgrid heating applications, enabled by the smaller generating capacities of next-generation nuclear reactor designs, could provide reliable heating to residences and industries without carbon emissions even during unexpected grid outages, like the Texas deep freeze seen in 2021. Some recent innovative ideas even postulate using the heat generated by used nuclear fuel for heating applications.
Many environmental projections now stress the need for net-negative carbon emissions, leading to substantial interest in carbon air capture, storage, and/or sequestration. The carbon sequestration process at scale will be highly dependent on the capacity factor of its energy source, requiring capacity factors upwards of 80% and heat to power ratios of 4 to 1. Next-generation nuclear reactors are uniquely equipped to power these sorts of operations, offering capacity factors in excess of 90% while not emitting carbon into the atmosphere. Reactor designers for the OPEN100 project have expressed interest in power carbon capture facilities. In the United States, little headway has been made in passing legislation that develops a nationwide carbon tax. However, investing in technology now that could support net negative carbon capture technology could still set us up for success if we ever do decide to implement a carbon tax.
Beyond Nuclear

Investing in non-baseload applications for nuclear power generation has the potential to spur unforeseen innovations for power systems beyond just nuclear reactors. Personal computers and the internet, for example, are often credited as being born out of the Department of Defense’s DARPA program. The US government could additionally have incentive and demonstration programs for renewable energy sources that would help bring the fundamental research from innovation hubs like the Department of Energy’s ARPA-E to market more quickly. While there are countless unknowns to be grappled with over the coming years about how to handle climate change and meet our emissions goals, we can be certain that innovation will be key in decarbonizing our future. This policy would support innovation in nuclear reactor applications in the United States and help us meet those goals.