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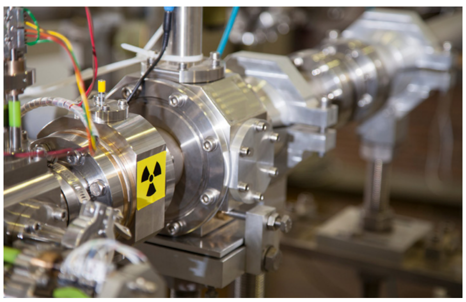
ENERGY COUNCIL INFO SERIES



Energy Generation Solutions: Small Modular Reactors

Carbon emissions are unlikely to become less politically or economically salient; however, the demand for plentiful, reliable power is equally unlikely to decline. Nuclear power is an obvious candidate to manage the tension between these priorities. Although nuclear has historically supplied 20% of the nation's energy, development of the traditional nuclear industry has all but stalled in the United States. The few ongoing nuclear projects are both past schedule and over cost. However, while the technology has yet to be fielded, small modular reactors (SMR) may be a way to restore innovation, affordability, and improved safety to the nuclear power industry. Promising clean energy and a safer, more flexible generation platform, SMRs will likely be a decisive tool to help America meet its carbon-reduction goals.

Key Facts:

- In contrast to more traditional bespoke designs, SMRs can offer potential construction cost savings by incorporating standardized, factory-fabricated modules produced at scale. Additionally, self-contained "multi-pack" reactor clusters are designed with integrated safety features, reducing the need for expensive containment structures and their accompanying costs.

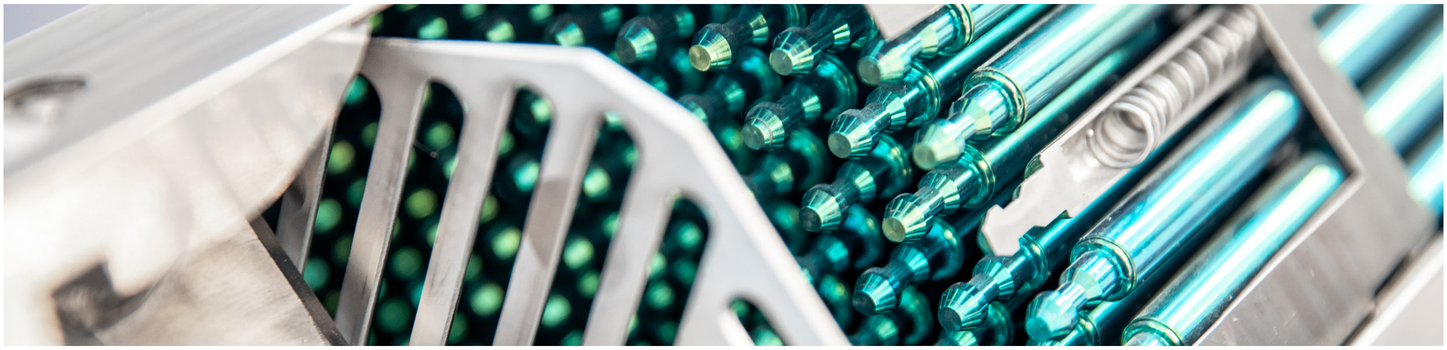
- SMRs can be more flexible than standard reactor designs. Multiple, separate reactor elements may be collocated to achieve desired power outputs. Operators need only pay for the capacity they expect to use. Further, their small physical size means SMRs may be employed in areas traditional reactors cannot.

- By utilizing novel cooling systems, many SMR designs can operate with significantly lower risk of meltdown, potentially allowing reactors to be sited closer to populated areas.

- SMRs may prove useful in managing the threat of nuclear proliferation. They often offer significantly smaller footprints and well as designed-in security features, allowing greater resistance to tampering and theft. SMRs can also operate using a wider array of nuclear fuels, reducing the risk of nuclear proliferation.

In the wake of high-profile nuclear accidents, like at Fukushima Daiichi in Japan, a fear of nuclear power has developed in the United States and many other Western nations. Such concern, combined with the complexity and expense of traditional reactor designs, has made nuclear energy a less attractive power option. However, a new generation of nuclear power technologies can offer the clean energy both developed and developing economies will need. SMRs can offer savings through economies of scale, with unit costs falling through mass production, as well as drastically lower risk of meltdown in some designs. However, in order to realize their full potential, policymakers must identify new regulatory approaches that take into account their improved safety features and standardized construction.

Technically speaking, SMR refers to a family of different reactor technologies incorporating modular design and construction elements, all producing 300 MWe or less. As might be expected, they are physically far smaller than



more traditional designs. One of their key cost-saving characteristics is that they can be akin to a 'kit' reactor—their constituent pieces are standardized and factory-fabricated with the reactors simply assembled on site—promising significant savings in design and construction. The standardized design and construction approach is a departure from traditional nuclear power plants, which rely on bespoke design and construction. And because of prefabricated designs, SMRs can not only benefit from the cost savings associated with standardized production, but can be easier and quicker to construct once on site.

Unsurprisingly, electric power produced by an individual reactor module is significantly less than many larger, more traditional designs; however, multiple reactor modules may be clustered together on the same site to reach the desired output. Rather more novel, individual reactors may be employed on their own to provide electricity or process heat for a variety of purposes at a much more localized level, including heavy industry, desalinization, and powering remote towns or military bases.

Contrary to the modular design ethos, the SMRs include a variety of designs, each offering valuable performance advantages. The simplest designs include light water cooling. Light water reactors, unlike the heavy water (D2O) designs that use the rare, heavy hydrogen isotope, deuterium, use regular water (H2O) for both coolant and to control the rate of nuclear reaction. Light water reactors are already proven and are known to nuclear regulators. Other designs incorporate more novel liquid metal or molten salt coolants. Liquid metal and molten salt designs both permit significantly higher operating temperatures, allowing greater energy capture at a significantly reduced risk of meltdown.

Perhaps the most significant benefit derived from particular novel coolant designs is that some can make a reactor meltdown materially unlikely. Some, though not all, of the novel SMR designs that require no water for cooling or reaction control, vastly lower the risk of explosive decompression or loss of cooling capacity in the event of a coolant breach. There is also a significantly reduced risk of uncontrolled radiation release with some of these designs, as molten coolants operate at near atmospheric pressure and their vastly higher boiling points make coolant loss unlikely. In addition, SMRs can be designed with additional safety features including automatic, convection-driven passive cooling that requires no external energy input, reducing the risk of failure due to an external power cutoff. Combined, these features can effectively negate the risk of reactor meltdown—like that which occurred in 2011 at the Fukushima Daiichi power plant.

The small size and modular nature of SMRs can offer additional benefits. In many cases, a reactor element's small footprint means the reactor can be located in areas where traditional reactors simply would not fit, like retired coal mining sites. Because of their improved safety and flexible sizing, SMRs can also potentially be employed closer to populated areas without increasing the risk to an area's inhabitants. Further, SMRs are often designed to be built underground offering even greater security against natural or human threats. If nuclear safety regulations keep pace with advancing technology, SMRs can be an outstanding option for moving the US energy market away from fossil fuels, offering industry and communities safe, reliable, and carbon-free power at an affordable price.

SMRs are not without critics, however. Some suggest that while SMR designs can be inherently safer than traditional light water reactors, they are not completely without risk. The metals used in some liquid metal reactor designs are often either corrosive or highly flammable, and they can lack a hardened, overarching containment structure. Advocates, in turn, consider the greatly reduced risk of meltdown to negate these concerns. Others suggest that smaller reactors remain at least somewhat insecure against direct action, like a terrorist attack. Emerging SMRs are, however, designed for continuous physical protection - from factory fabrication to operation - and benefit from superior safety features that can potentially make a catastrophic radiation leak because of tampering nearly impossible. Finally, some designs utilize non-traditional nuclear fuels that make theft of fuel or waste less attractive. While some risk is always present in any energy production method, SMR technologies may promise a valuable combination of security and utility.