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King Abdullah Petroleum Studies and Research Center

Commentary

Are Small Modular Reactors a Good Option for Saudi Arabia?

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There are more than 50 SMR technologies worldwide at different stages of technological development – but none of them are commercial or operational yet.

Since the start of nuclear power in the 1950s, nuclear generation technology has continually transformed and developed. Following the three major nuclear accidents, Three Mile Island, Chernobyl and Fukushima, nuclear power has become more robust, safer and more secure.

The average capacity of nuclear reactors has grown from 50 megawatts electric (MWe) in the 1950s to around 1.65 giawatts electric (GWe) today. Nuclear capabilities are concentrated mostly around Europe, North America, and East and South Asia. The United States (U.S.) is the largest producer of nuclear power, while France has the largest share of electricity generated by nuclear power. Nuclear power today provides 11% of the world's electricity, with 454 nuclear reactors operating in 30 countries, and 54 plants under construction – including 11 in China, seven in India, and six in Russia.

Climate change concerns have led to the widespread acceptance of the importance of environmental sustainability. The international community is calling for the adoption of stringent environmental regulations and is exerting pressure on countries to curb their carbon dioxide emissions. As such, the concerns around current carbon-based electricity systems that are mainly powered by hydrocarbon fuels are now heightened. Although renewable energy technologies have grown in capacity and reduced in cost, replacing existing capacity, especially base load electricity generation, with renewables remains challenging. All this makes a strong case for using nuclear energy as a reliable and cleaner energy source, and to diversify national energy mixes.

Innovations in nuclear reactor design have led to the emergence of smaller reactors with the potential to overcome many challenges and problems inherent in large reactors (LR). The problems associated with LRs include the necessity for large initial investments, long construction lead times and their incompatibility with some national grids. The massive scale of LR construction and development projects leads to estimate delays and huge cost overruns, which are often eventually borne by governments.

Small modular reactors (SMRs) are advanced nuclear reactors with the potential to mitigate some of the high risks associated with LRs. "Small" denotes <300 MWe; it could describe a reactor of 50 MWe capacity or even a micro reactor of 10-20 MWe. "Modular" denotes a reactor design that could be factory-built and then deployed using multiple identical standard modules at a given nuclear power plant site.

There are currently over 50 SMR technologies worldwide at different stages of technological development, but none of them are commercial or operational yet. SMRs have expanded the potential for nuclear energy use to include electricity generation, desalination, hydrogen production, central heating, unconventional oil recovery, industrial heat use, power transmission to remote and off-grid areas, and integrated nuclear-renewable projects.

Many countries – especially newcomer countries with smaller grids and less-developed infrastructure, or advanced countries supplying power to remote areas and/or for specific applications – are looking at using SMRs.

The many potential advantages associated with SMRs are detailed below:

Design

SMRs benefit from their modularity, serial production, and factory-fabricated simple designs, which often have inherent or passive safety systems, with lower initial investment and shorter simplified design construction times (~3 years as opposed to 7-10 years). Their design allows for simplified production units, flexible outages, the economies of serial production, manageable project sizes, and stepwise investments of standardized concepts. Units can be expanded at any time (buy one module and add others later).

Economics

SMRs bring about many economic benefits. These include lower investment risks, lower upfront capital costs per unit, faster technology learning (due to short construction times), economies of scale, off-site fabrication, improved quality control, a substantially shorter time to market, shorter constructing schedules, simplified designs and a lower overall operating cost. The successive addition of multiple units at the same site would lower the capital cost per added unit relative to the previous unit and would limit the exposure to cost escalation risks.

Even though there is an initial economy of scale, there is a higher cost per unit (MWe) for small-capacity SMRs compared with LRs. This is because the average investment and operating costs per unit of electricity are decreasing with respect to increasing plant sizes. However, when we compare the overall costs, SMRs are cheaper per unit of electricity than LRs. For example, Bloomberg New Energy Finance estimates the cost of SMR to ranges between $2/MW (GE Hitachi) and $4/MW (Korean Electric Power Company's [KEPCO's] system-integrated modular advanced reactor [SMART]). This compares with a higher cost for LR of $9.8/MW (Westinghouse's AP-1000).

Finance

SMRs are smaller and easier to finance than LRs, minimizing escalation charges and avoiding the demand for "risk premium." This helps build investor confidence and allows for stepwise investments.

Grid compatibility

Demand uncertainty or declining demand, especially in liberalized electricity markets, makes traditional LR nuclear expansion economically risky; SMRs mitigate that risk. It is difficult to incorporate LRs into some existing national grids, but SMRs can be more easily accommodated. The loss of a smaller unit in an SMR is not as disruptive as the loss of a single large reactor to a national grid.

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Safety

SMRs are safer than LRs and, because of their smaller size, are easier to cool. As SMRs have less thermal energy production per reactor than LRs, the risks of a core meltdown and releasing radioactive material are reduced. Most new SMR designs provide for passive safety rather than the engineered safety systems built into LRs, which improves their overall safety level.

However, SMRs do face some challenges, including:

Technology development

Currently there are no operational or commercially available SMRs, so the technology is pilot-tested but not necessarily commercially viable. Moreover, first mover's disadvantage means the learning curve of SMR technology builds on significantly different nuclear technology. Moreover, there are no reference cases to learn from, which adds to the challenge of adopting the technology. The revolutionary design of SMRs means that the pilot and demonstration phase is often lengthy and requires government backing.

Legal issues

The nature of manufacturing SMRs, including fabricating off-site and transporting to the location, creates cross-border license, liability and regulatory issues that have to be navigated for the first time. This is especially true for first-of-a-kind (FOAK) reactors.

Saudi Arabia has announced plans to launch a nuclear energy program as part of its energy diversification targets.

Economics and finance

Investments in SMRs are subject to regulatory risk, public sentiment and acceptance, and national energy policies. The risks and costs are higher for first units, though subsequent units are expected to be cheaper.

Safety and security

SMRs are still nuclear reactors and carry all the risks of nuclear power technology, albeit on a smaller scale. Most SMR designs share the same fuel cycle challenges (proliferation concerns, spent fuel management, and decommissioning) that plague the nuclear energy industry. However, some SMR designs avoid or reduce some of these risks dramatically.

The status of SMRs in Saudi Arabia

Earlier this year, Saudi Arabia announced plans to launch a nuclear energy program of 2-3 GW, as part of its energy diversification targets. The shortlisted vendor countries include China, South Korea, France, Russia and the U.S.

In 2015, Saudi Arabia signed an agreement with South Korea to conduct a feasibility study to develop and build at least two SMRs. The study looked at the possibility of using Korea's SMART FOAK SMR in Saudi Arabia, in light of the continuously deepening Saudi-Korean bilateral relations since 1962 and the growing partnerships in various fields, especially since 2011 in the peaceful use of nuclear energy. There have been several research partnerships between the two countries, alongside joint development and training, and most recently, the launch of the ministerial-level Saudi-Korean Vision 2030 aimed at strengthening partnerships between the two countries in a more institutional way.

The SMART project presents opportunities for the Kingdom, including the prospect of scientific and technical participation in developing the reactor. The Kingdom can play an active role in developing, testing, deploying and marketing the SMART reactor.

General information about the project:

- A SMART is a small integral pressurized water reactor advanced SMR.
- A SMART is designed to generate electricity (up to 100 MWe) and has thermal applications, such as seawater desalination. It has a design life of up to 60 years and a three-year refueling cycle.
- The cost of the first SMART unit, to be built in collaboration with 12 Korean companies, led by KEPCO, is estimated at $1 billion.
- The Korea Atomic Energy Research Institute designed an integrated desalination plant based on the SMART reactor, which produces 40,000 cubic meters per day of water and 90 MW of power at less than the cost of gas turbines.

Saudi Arabia is serious about deploying SMRs in the Kingdom. In addition to its agreement with South Korea, in December 2017, Saudi Arabia signed a cooperation agreement with China on a joint feasibility study to develop another SMR technology, high-temperature gas-cooled reactors. The world's first high-temperature gas-cooled reactor pebble-bed module, HTR-PM, is under construction in Shedwan, China. The plant will initially include two HTR-PM double reactor units driving one 210 MW steam turbine. Construction began in late 2012, but it is yet to be commercially operational, having been scheduled to start by 2018. HTR-PM is partly based on the HTR-10 prototype reactor, which was successfully operated at full power in 2003.

Similar to Saudi-Korean relations, Saudi Arabia and China share an important partnership that builds on decades of strong relations. Saudi Vision 2030 (SV2030) intersects with China's Belt and Road Initiative. The two countries have signed many commercial agreements relating to the oil, petrochemical, mining, electricity, ceramic and port industries, among others.

Choosing a nuclear vendor to build a reactor is essentially a strategic decision based upon many factors, perhaps most importantly the bilateral relations with the candidate countries. The relationship must be strategic and enduring, and able to withstand the dynamics of domestic and international politics. The lifecycle of SMRs, including their construction, operation and maintenance, and eventually, waste disposal, will be significantly shorter than that of LRs.

SV2030 emphasizes increasing localization by building human capacity and increasing industrial development. The localization of SMR technology in Saudi Arabia would offer great economic and developmental benefits and would contribute to the realization of SV2030's National Transformation Program's long-term targets and goals.

Deploying SMRs in the Kingdom will allow it to better utilize its oil reserves in the long run and meet its increasing domestic energy demand. It will also enable the development of human capital through knowledge transfer, and the growth of public and private sector investments through the development of the SMR value chain.

This commentary is part of a study on Saudi Arabia's nuclear energy program, under the Energy Transitions and Electric Power program. For more details, see an upcoming paper, "Saudi Arabia's Nuclear Energy Program," expected to be published in December 2019.

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