Nuclear's Continuing Evolution

Light Water Reactor

Uses water to cool uranium fission reactions

—

Needs an operator to shut-down

—

Requires uranium enrichment

Small Modular Reactor

Most are similar to LWRs but have been reduced in size and complexity

—

Can shut down without an operator

—

Requires slightly more fuel with uranium enrichment

Advanced Reactor

Uses coolants ranging from water to molten salt to liquid metal and even gases

—

Can be "walk away safe"

—

Can use enriched & depleted uranium, or used nuclear fuel

2015 → 2020 - 2025 → 2025 - 2030

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Nuclear's Continuing Evolution

By Samuel Brinton

After more than 60 years of operation, the nearly 100 light water reactors (LWRs) operating in the U.S. supply nearly 20% of the U.S.'s electrical generation and 64% of its carbon-free electricity. These plants are a critical element in the low-carbon emissions energy mix that must remain in operation, and they are an American technological and technical accomplishment to be proud of. But what's the next step in nuclear power's evolution? Just as some companies require supercomputers and other companies require laptops, the next generation of nuclear engineers are designing advanced and innovative reactors to provide different types of power for the very different energy needs around the globe.

Small modular reactors (SMRs), defined by the International Atomic Energy Agency as anything less than 300 MWe (or less than one-fourth the size of a typical LWR), might hold the key to a transition toward advanced nuclear reactors. SMRs are about to begin the final stages of commercial development. With a lower initial capital investment and shorter construction timeline than LWRs, SMRs could replace aging and carbon-emitting coal power plants. The next generation of nuclear reactors hold even greater promise of addressing challenges faced by the nuclear industry including nuclear waste management, proliferation concerns, and costs of construction.

The SMRs and advanced reactors can complement light water reactors by providing a broader range of applications. Both can provide a dependable electricity source to sparsely populate areas or regions unattached to a grid, and may be deployed easier and for less upfront cost. Similarly, both SMRs and advanced reactors can provide distributed generation of process heat to industrial sites, such as a desalination plant; enable grid independence at critical facilities such as military bases; and even deliver load following electrical production.

Advances in Design

The following information provides a quantitative context to the evolution from the light water reactor to the small modular reactor and advanced reactor. Please note that most values for the small modular reactors and advanced reactors are estimates.

	Light Water Reactor	Small Modular Reactor	Advanced Reactor
Design Features	Uses water to cool uranium fission reactions	Most are similar to LWRs but have been reduced in size and complexity	There is a range of designs with coolants ranging from water to molten salt to liquid metal and even gases
Size[1]	A range of 800 MWe to 1600 MW[2]	Many designs are less than 300 MWe[3]	Scalable from 2 MWe[4] to 1200 MWe
Cost to Construct ($/kWe)[5]	$2600 to $6600[6] with averages at around $4000[7]	Estimated at $3200 to $16300[8] with average at $4,000[9]	Estimated between $2500[10] to $3900[11] though early in estimation
Time to Construct	4.5 years[12] to 6 years[13] on site with large modules	Estimated at 1.5 to 2.5 years[14] in factory modules	Estimated at 1 to 5 years[15] with factory or on-site modules
Spent Fuel (MT/year)[16]	An average of 20 MT[17]	Similar but slightly higher at 33.6 MT[18]	Some produce 0.5 to 1 MT and can use 55 MT[19]
Operations	Existing reactors need an operator to shut-down the reactor. Some being built won't need immediate operator intervention	Some SMRs can shut down without an operator and some won't need immediate operator intervention	Many designs can be "walk away safe" without operator intervention
Proliferation Risk	Requires uranium enrichment	Requires slightly more fuel with uranium enrichment[20]	Can use enriched uranium, depleted uranium,[21] or used nuclear fuel[22]

Endnotes

1. This is measured in Megawatts-electric (MWe). One MWe can roughly power 1,000 homes.
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5. This is the estimated overnight cost in $/kWe (dollars per kilowatt-electric).
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12. Ray Henry, "Construction time uncertain for Vogtle nuclear project", PennEnergy, August 29, 2014, Accessed March 13, 2015. Available at: http://www.pennenergy.com/articles/pennenergy/2014/08/construction-time-uncertain-for-vogtle-nuclear-project.html.
13. Kristi Swartz, "Timeline for U.S.'s newest reactor stretches into 2019", E&E News, January 30, 2015, Accessed March 13, 2015. Available at: http://www.eenews.net/stories/1060012611.
14. Ondrey,"Modular design would shorten construction times for nuclear plants", *Chemical Engineering*, Volume 116, Issue 10, p. 16.
15. Transatomic Power, Technical White Paper, V 1.0.1, March 2014, http://transatomicpower.com/white_papers/TAP_White_Paper.pdf.
16. This is measured in metric tons of used nuclear fuel produced or consumed per year for one Gigawatt-electric year of capacity. As a note, an elephant generally weighs roughly one metric ton. http://www.wisegeek.org/what-is-a-metric-ton.htm.
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19. Samuel Brinton, "Used nuclear fuel storage options including implications of small modular reactors". Dissertation. Massachusetts Institute of Technology, 2014. Accessed March 13, 2015. Available at: http://dspace.mit.edu/handle/1721.1/90067 .
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