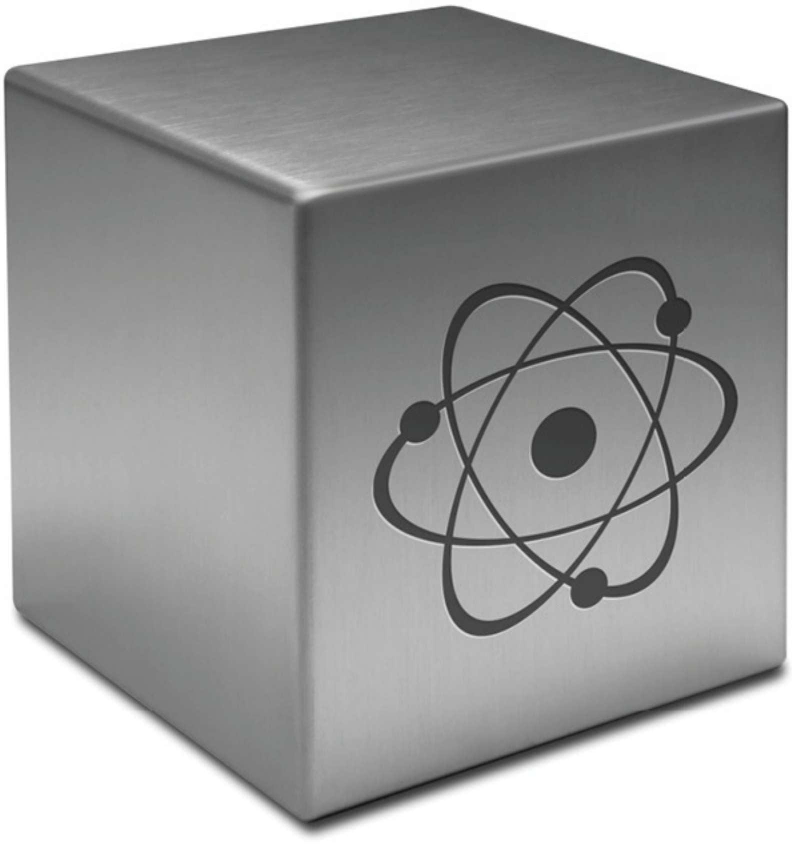
INTRODUCING THE

ADVANCED NUCLEAR INDUSTRY



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About Third Way

Third Way is a think-tank that answers America's challenges with modern ideas aimed at the center. We advocate for private-sector economic growth, a tough and smart centrist security strategy, a clean energy revolution, and progress on divisive social issues, all through a moderate-led U.S. politics.

We represent Americans in the "vital center"—those who believe in pragmatic solutions and principled compromise, but who too often are ignored in Washington.

Too often, our national debates are defined by the rigid or outdated orthodoxies of both the left and right. This polarization leads to ideologically driven policies and political gridlock, and it drowns out the voices of millions of Americans in the forgotten middle.

We believe there is a better way, a "third way"—one that discards the false choices presented by both sides. This third way philosophy is ideal for fostering the most effective and emergent approaches to major problems—ones that can attract the plurality of citizens who represent the political center and whose support is crucial to effective and credible governance.

Our ideas have been used by the President, members of Congress, governors, mayors and countless political candidates. Based on our record, we've been labeled as "the future of think tanks," "incorrigible pragmatists," "radical centrists," and the "best source for new ideas in public policy."

Our Clean Energy Work

Third Way has rejected the ideological rigidity of the climate change debate, which pits climate deniers against those who believe renewables are the only answer. Under our Clean Energy Program, we have developed a campaign to ensure the U.S. leverages all of our energy resources as part of a climate solution, with a focus on commercializing advanced nuclear energy, cutting the carbon emissions from fossil fuels, and moving freight off American roads and onto our rails and waterways. More than a dozen of our proposals have been introduced as legislation or executive orders, and three have become law.

Throughout its existence, Third Way has been an advocate for the safe and reliable use of nuclear energy as a key tool to address the twin challenges of climate change and growing global electricity demand. From examining the technical benefits of small modular reactors to looking at how shutting down the current nuclear fleet would impact carbon emissions, we strongly believe it is critical that any national energy conversation includes nuclear power.

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Introduction

The American energy sector has experienced enormous technological innovation over the past decade in everything from renewables (solar and wind power), to extraction (hydraulic fracturing), to storage (advanced batteries), to consumer efficiency (advanced thermostats).

What has gone largely unnoticed is that nuclear power is poised to join the innovation list.

A new generation of engineers, entrepreneurs and investors are working to commercialize innovative and advanced nuclear reactors.

This is being driven by a sobering reality—the need to add enough electricity to get power to the 1.3 billion people around the world who don't have it while making deep cuts in carbon emissions to effectively combat climate change.

Third Way has found that there are more than 40 companies, backed by more than $1.3 billion in private capital, developing plans for new nuclear plants in the U.S. and Canada. The mix includes startups and big-name investors like Bill Gates, all placing bets on a nuclear comeback, hoping to get the technology in position to win in an increasingly carbon-constrained world.

This report introduces you to the advanced nuclear industry in North America. It includes the most comprehensive set of details about who's working on these reactor designs and where. We describe the money and momentum building behind advanced nuclear, and how the technology has evolved since the Golden Age of Nuclear.

To be clear, this is not your grandfather's nuclear technology. While developers in some cases are working off of technology designs conceived in our national laboratories during the 1950s and 1960s, the advanced reactor technologies being developed are safer, more efficient and need a fraction of the footprint compared to the nearly 100 light water reactors (LWRs) that provide almost 20% of the U.S.'s electricity today (and 65% of its carbon-free power). New plants could be powered entirely with spent nuclear fuel sitting at plant sites across the country, built at a lower cost than LWRs and shut down more easily in an emergency.

The need for nuclear power has never been clearer. To stem climate change, the world needs 40% of electricity to come from zero-emissions sources, according to the International Energy Agency (IEA). While we can and must grow renewable energy generation, it alone will leave us far short of meeting that demand, the U.N. Intergovernmental Panel on Climate Change (IPCC) and the U.S. Environmental Protection Agency (EPA) have said. This is why the IPCC in November issued an urgent call for more non-emitting power, including the construction of more than 400 nuclear plants in the next 20 years. That would represent a near doubling of the 435 plants operating globally today.

Nuclear power is on the cusp on a comeback. The technology may be the best opportunity we have to address climate change and meet the world's growing energy needs.

Introducing the Advanced Nuclear Industry

The energy sector has experienced enormous technological innovation over the past decade in everything from renewables (solar power), to extraction (hydraulic fracturing), to storage (advanced batteries), to consumer efficiency (advanced thermostats). What has gone less noticed is that nuclear power is poised to join the innovation list. Third Way original research has identified a new generation of engineers, entrepreneurs, and investors, along with several established nuclear companies, who are working to commercialize innovative and advanced nuclear reactors in North America. In total, we have found over 45 projects in companies and organizations working on small modular reactors based on the current light water reactor technology of today's reactors, advanced reactors using innovative fuels and alternative coolants like molten salt, high temperature gas, or liquid metal instead of high-pressure water, and even fusion reactors, to generate electricity.

These companies are being built and funded because the innovators and investors see profit in creating an answer to the global energy paradox – there are 1.3 billion people in the world without access to reliable electricity; they will get that electricity, and advanced nuclear can provide it to them while cutting global carbon emissions. Our table and map of the advanced nuclear industry in North America is the most comprehensive listing to date of who is working on these reactor designs. In compiling this list, four important trends became clear:

1. Coast to Coast: Research is not isolated to one state or even one coast. The companies and organizations leading the design revolution reach up and down both the East and West coasts of the United States and into Canada. In all, twenty different states host entities researching advanced nuclear energy.

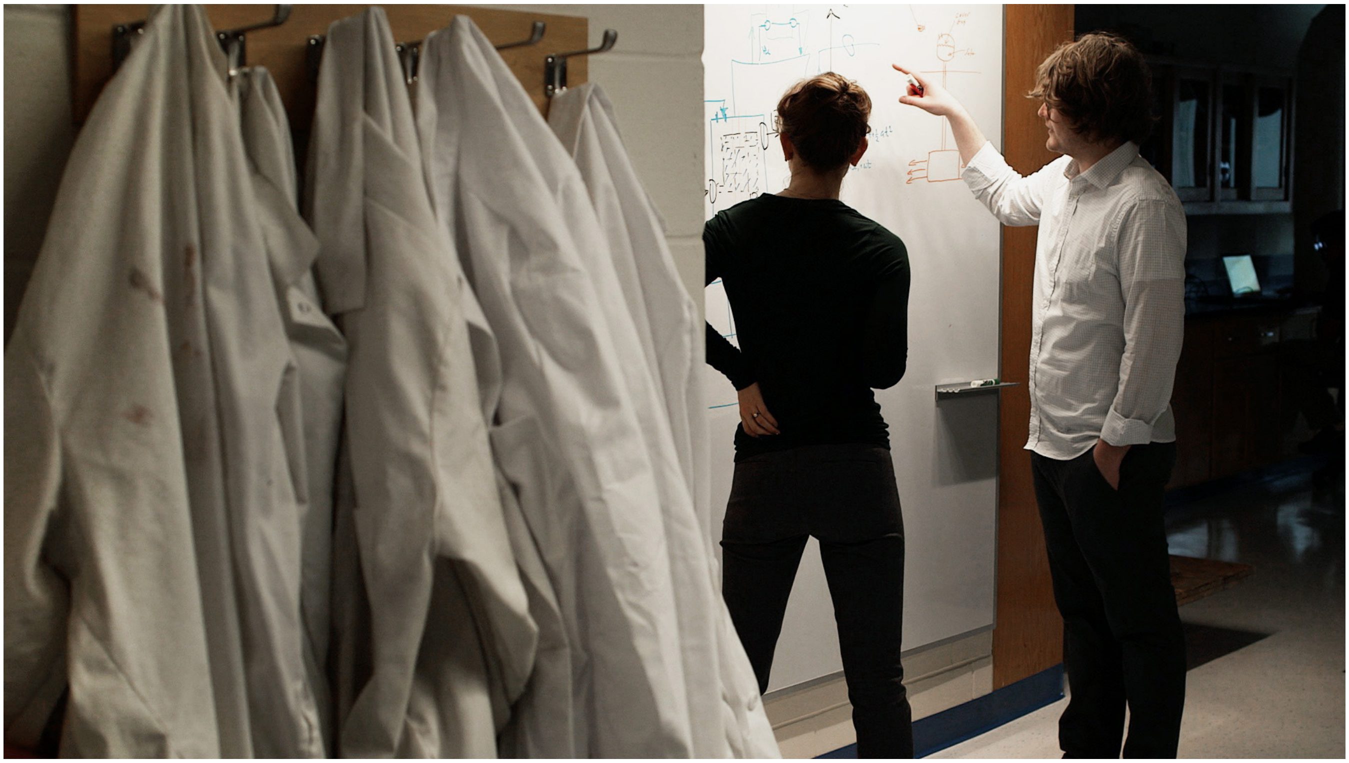
2. One Size Doesn't Fit All: In interviews Third Way conducted with many of the companies on this list, we found real diversity in size and structure, ranging from lone entrepreneurs, to venture capital supported university spin-offs, to large international corporations. Each is making strides and bringing a unique perspective to the industry.

3. A Compendium of Coolants: While water does a great job of cooling and moderating the atomic fissions of nuclear reactors, the next generation of nuclear reactors is looking to broaden our options. These include liquid metal, high temperature gases, and molten salt. Nuclear reactors using these coolants can be even safer than most light water reactors. The higher operating temperatures of coolants like helium, liquid metals, and molten salts more readily lend themselves to industrial applications requiring high temperature process heat.[1]

4. Not Just Fission Anymore: Along with the evolution from large light water reactors to small modular light water reactors and beyond, Third Way has found major investment and interest in nuclear fusion from both small and large companies. Though this technology has much left to refine before commercialization, the growth has been staggering.

When thinking of the emerging advanced nuclear industry, it is important to understand how it compares to other sectors with a number of potentially new entrants. Let's take the Internet. On the surface, there are similarities. As with the Internet today, the advanced nuclear space includes startups led by recent Ph.D. graduates, established Fortune 500 multinationals, and everything in between. And just like Internet companies, financing includes seed capital provided by angel investors, investments by established venture capital firms, and companies spending their own capital on significant R&D budgets.

The differences between the advanced nuclear companies and the companies spurring the latest Internet revolution are just as important. While the latest software or hardware improvement can take significant funding and research, the dollars and time required are a relative pittance in comparison to the funding necessary and regulation that must be navigated to design and build a new nuclear reactor. But despite these obstacles, nearly 50 companies and organizations are moving ahead, and a decade from now we may be seeing a brand new reactor revolutionizing the energy industry.



November 2014: Leslie Dewan and Mark Massie at MIT.
Source: Sareen Hairabedian, Brookings Institution.

Advanced Reactor Development:

A Nascent Industry

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North American Advanced Reactor Projects

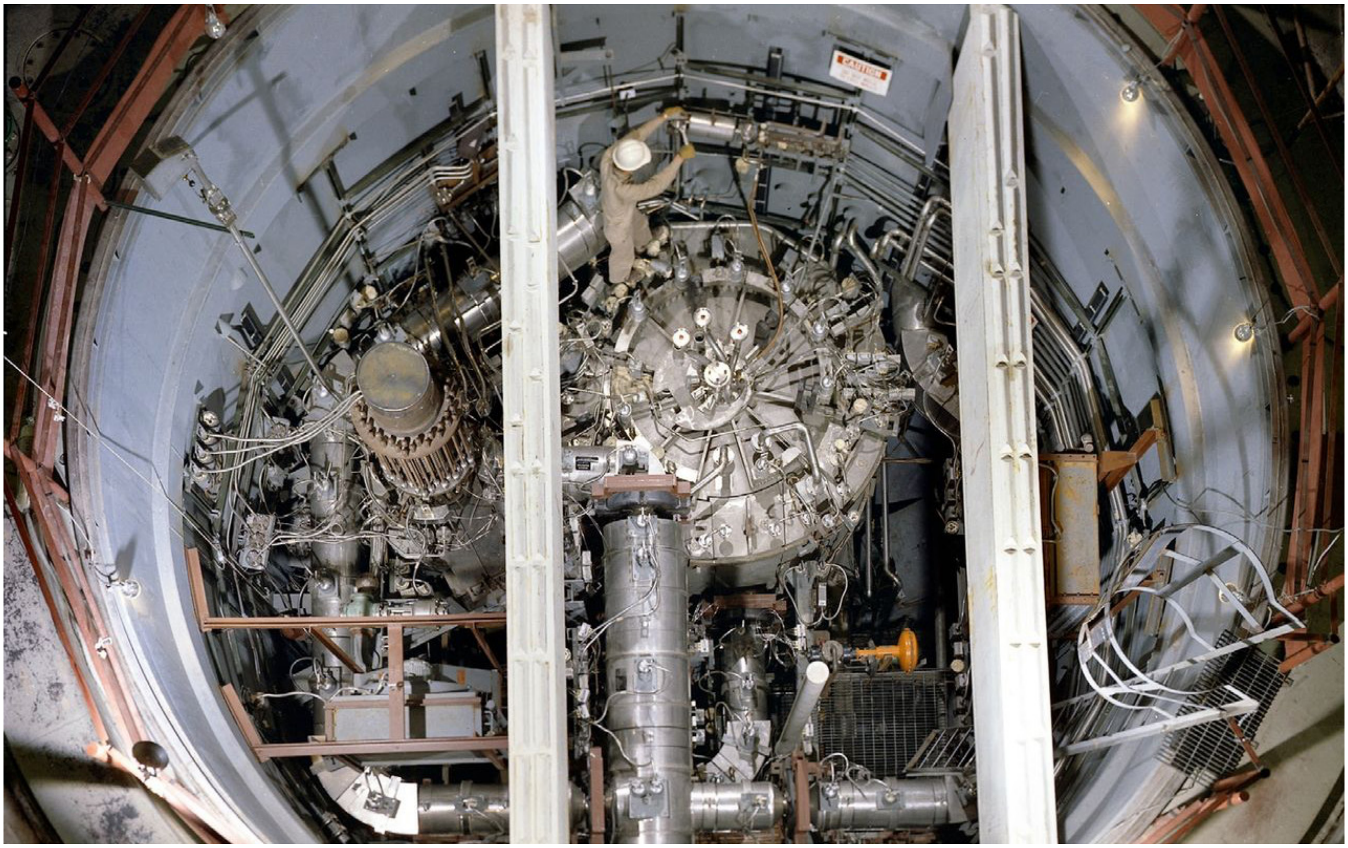
Company	Location	Design Type
Transatomic (TAP)	Cambridge, MA	Molten Salt Reactor
Terrestrial Energy (Integral MSR)	Mississauga, Canada	Molten Salt Reactor
Martingale Inc (Thorcon)	Stuart, FL	Molten Salt Reactor
Flibe Energy (LFTR)	Huntsville, AL	Molten Salt Reactor
Oak Ridge National Laboratory (SmATHR)	Oak Ridge, TN	Molten Salt Reactor
Massachusetts Institute of Technology (FHR)	Cambridge, MA	Molten Salt Reactor
University of California, Berkeley (PB-FHR)	Berkeley, CA	Molten Salt Reactor
General Electric-Hitachi (PRISM)	Wilmington, NC	Liquid Metal-cooled Fast Reactors
Advanced Reactor Concepts (ARC-100)	Reston, VA	Liquid Metal-cooled Fast Reactors
Thorenco	San Francisco, CA	Liquid Metal-cooled Fast Reactors
Argonne National Laboratory (STAR)	Lemont, IL	Liquid Metal-cooled Fast Reactors
LakeChime (L-ESSTAR)	Williamsburg, VA	Liquid Metal-cooled Fast Reactors
Gen4 Energy (G4M)	Denver, CO	Liquid Metal-cooled Fast Reactors
Virginia Tech and ADNA Corp. (GEMSTAR)	Blacksburg, VA	Liquid Metal-cooled Fast Reactors
University of California, Berkeley (ENHS)	Berkeley, CA	Liquid Metal-cooled Fast Reactors
Terrapower (TWR)	Bellevue, WA	Liquid Metal-cooled Fast Reactors (Variant)
Starcore Nuclear	Montreal, Canada	High Temperature Gas Reactor
General Atomics (EM2 and MHR)	San Diego, CA	High Temperature Gas Reactor
Areva (SC-HTGR)	Bethesda, MD	High Temperature Gas Reactor
DOE Next Generation Nuclear Plant	Bethesda, MD	High Temperature Gas Reactor (Collaborative Project)
Hybrid Power Technologies (Hybrid)	Kansas City, KS	High Temperature Gas Reactor (Variant)

X-Energy	Greenbelt, MD	Pebble Bed Modular Reactor
Northern Nuclear (Leadir-PS100)	Cambridge, Canada	Pebble Bed Modular Reactor (Lead Cooled)
UPower	Mountain View, CA	Nuclear Battery (Solid State)
University of Missouri	Columbia, MO	Nuclear Battery
CityLabs (NanoTritium)	Homestead, FL	Nuclear Battery
Dunedin (SMART)	Toronto, Canada	Nuclear Battery
Widetronix	Ithaca, NY	Nuclear Battery
SuperCritical Technologies	Seattle, WA	Super-Critical CO2 Reactor
Lightbridge	Tysons Corner, VA	Designs Advanced Nuclear Fuels
B&W Company and Bechtel Power Corp. (mPower)	Charlotte, NC	Small Modular Reactor (PWR)
NuScale Power (NuScale)	Corvallis, OR	Small Modular Reactor (PWR)
Radix Power and Energy Corp. (RADIX)	Setauket, NY	Small Modular Reactor (PWR)
Holtec (SMR-160)	Jupiter, FL	Small Modular Reactor (PWR)
Westinghouse (SMR)	Fulton, MO	Small Modular Reactor (PWR)
General Atomics (TPS)	San Diego, CA	Small Modular Reactor (PWR)
Helion Energy	Redmond, WA	Fusion
National Ignition Facility	Livermore, CA	Fusion
General Fusion	Burnaby, Canada	Fusion
Lawrenceville Plasma Physics	Middlesex, NJ	Fusion
Lockheed Martin	Bethesda, MD	Fusion
General Atomics	San Diego, CA	Fusion
Tri Alpha	Foothill Ranch, CA	Fusion
Princeton Plasma Physics Laboratory	Princeton, NJ	Fusion
Fusion Science Center	Rochester, NY	Fusion
HyperV Technologies	Chantilly, VA	Fusion
Magneto-Inertial Fusion Technologies (MIFTI)	Tustin, CA	Fusion
NumerEx	Albuquerque, NM	Fusion
Z Machine	Albuquerque, NM	Fusion

Evolution of Nuclear Power

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 based on light water reactors 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.



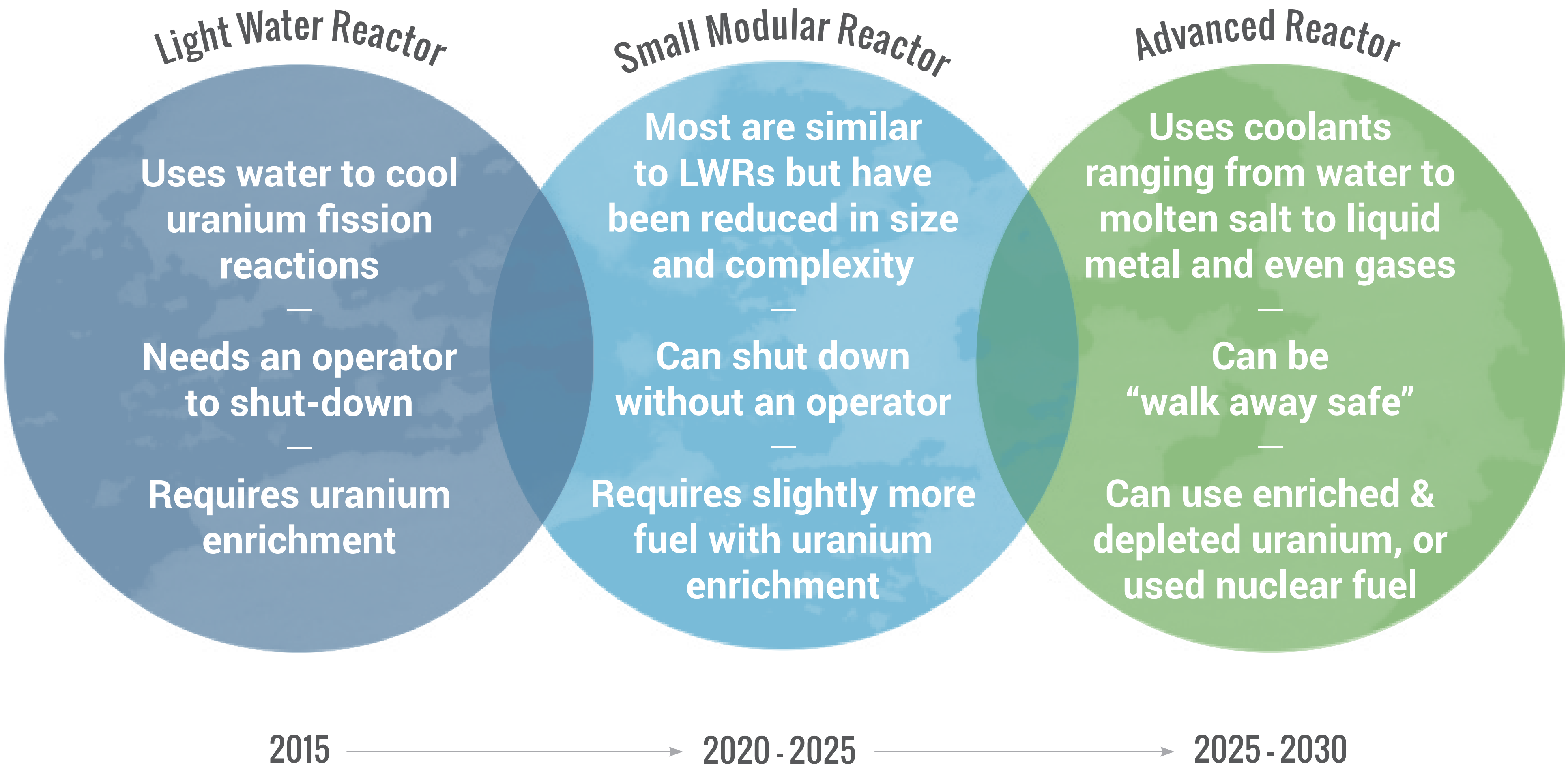
1964: Molten salt reactor at Oak Ridge.
Source: Wikimedia Commons

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[2]	A range of 800 MWe to 1600 MW[3]	Many designs are less than 300 MWe[4]	Scalable from 2 MWe[5] to 1200 MWe
Cost to Construct ($/kWe)[6]	$2600 to $6600[7] with averages at around $4000[8]	Estimated at $3200 to $16300[9] with average at $4,000[10]	Estimated between $2500[11] to $3900[12] though early in estimation
Time to Construct	4.5 years[13] to 6 years[14] on site with large modules	Estimated at 1.5 to 2.5 years[15] in factory modules	Estimated at 1 to 5 years[16] with factory or on-site modules
Spent Fuel (MT/year)[17]	An average of 20 MT[18]	Similar but slightly higher at 33.6 MT[19]	Some produce 0.5 to 1 MT and can use 55 MT[20]
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[21]	Can use enriched uranium, depleted uranium,[22] or used nuclear fuel[23]

Nuclear's Continuing Evolution



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