THIRD WAY

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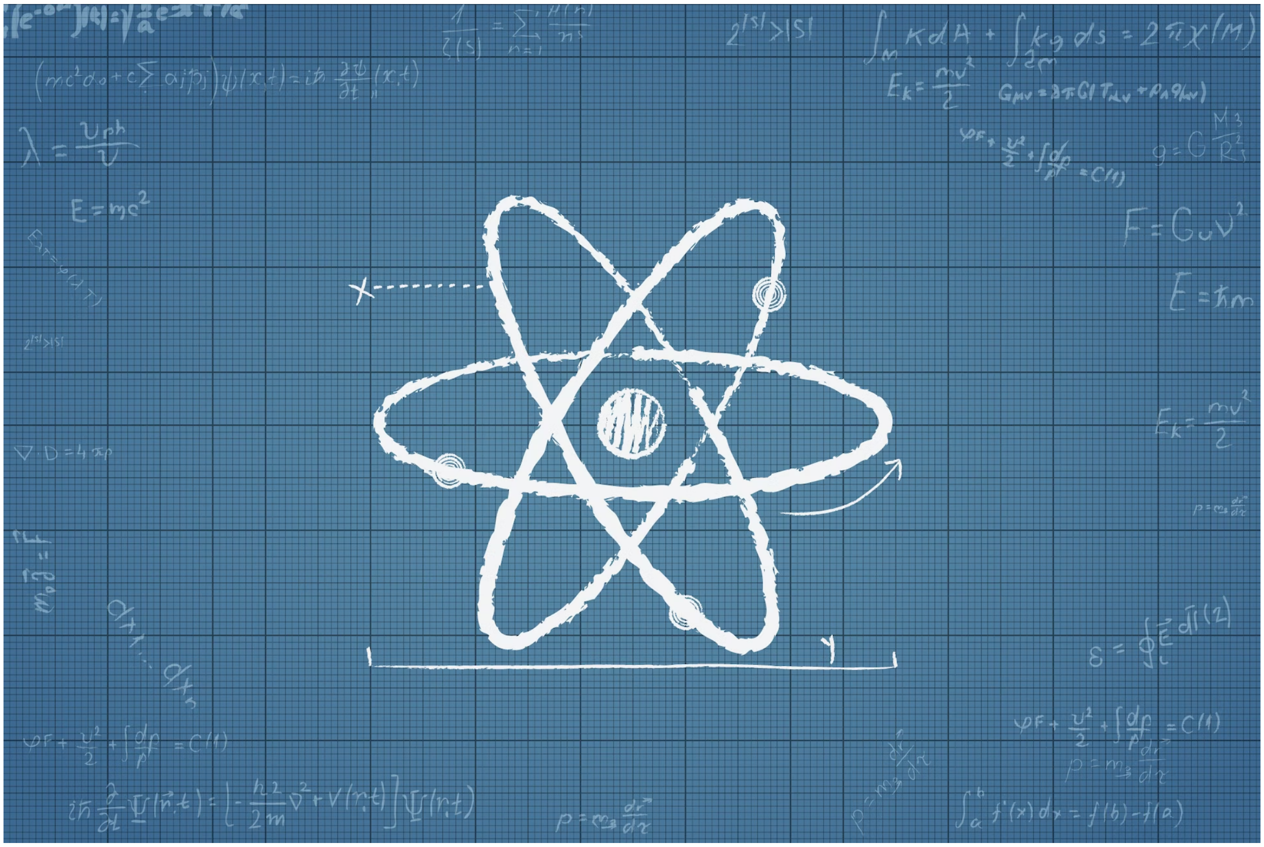
Why FOAK Nuclear Reactors are So Expensive—and Worth the Cost



Ryan Norman
Senior Policy Advisor, Climate and Energy Program

Alan Ahn
Deputy Director for Nuclear
@alanahn81

Rowen Price
Policy Advisor for Nuclear Energy
@RowenPrice

So, you've heard a lot about expensive new nuclear projects. But *why* is new technology so expensive to build? The answer is simple—we don't really know what we're doing yet, and that's OK. Standing up any new industry incurs significant additional costs. A brief example: automobiles were once considered a luxury item typically ranging between costs of $65,000 and $100,000 in today's dollars. Then, the Model T changed the industry and the market by offering a vehicle at less than half the price of the competition.

What is not as often recognized in this story is the substantial investment in engineering, infrastructure, and the time needed to make Ford's breakthrough possible. Advanced nuclear energy may not take the same path as the Model T, but it is facing the same challenges to commercialization, which we're seeing across emerging clean energy technology, such as offshore wind and enhanced geothermal. Commercializing a technology requires developing the knowledge, infrastructure, and supply chains necessary to support future production. Some of these costs can be spread across future products, and some are uniquely attributable to early projects.

When it comes to nuclear energy, the stakes are both economic and deeply geopolitical. Global energy partnerships for nuclear power plants create 100-year relationships between the host and supplier countries. The Chinese and Russian governments fully back their state-owned nuclear companies in winning export deals to expand their geopolitical influence. Despite these cost challenges, the US must continue to support its burgeoning nuclear industry to secure the massive economic and geopolitical gains that are at stake. Every market that our competitors seize risks undermining the United States' security and diplomatic interests, as well as its ability to set the highest global standards for safety, security, and nonproliferation. Let's take a look at what first-of-a-kind (FOAK) is and what factors are contributing to the cost challenges of new nuclear.

What is a First-of-a-Kind Technology?

First-of-a-Kind, or FOAK, refers to the first model of a new generation where costs are expected to be significantly higher than subsequent commercialized models. These commercialized future models are then referred to as Nth-of-a-kind, or NOAK. [1] By the time NOAK is achieved at roughly the 5th reactor of a kind, the primary hurdles for new builds are siting and workforce considerations rather than supply chain and operational infrastructure.

Unique first steps are required for FOAK deployments, including developing supply chains and production experience that doesn't currently exist. As a result, project cost profiles for new nuclear technologies can be much more difficult to estimate in the early stages. Cost estimate confidence and production efficiency improves as a project continues to develop from design to construction and with each successive build.

What are Unique FOAK Costs?

Project Cost Estimate Development

Large energy projects use project cost estimates (PCEs) that are typically based on industry standards. PCEs are organized as:

- Low to high-end ranges within five classes from least developed estimate (Class 5) to most developed estimate (Class 1). Projects begin at a Class 5 level representing a broad cost range and less expected accuracy.

- As a project develops, initial estimates are updated based on financial incentives, firm tender offers, reprojected work needs, and inflation until a Class 1 estimate is completed and a project is ready for construction.

- Supply chain costs are also developed through the bid and tender process—meaning FOAK projects incur significantly higher supply chain costs due to limited options for new components and an inability to reduce costs by ordering at scale.

Part of the conversational disconnect around "soaring" costs is based on a misunderstanding of this PCE pathway. For example, DOE's Advanced Reactor Demonstration Project (ARDP) supported Terrapower's Natrium and X-energy's Xe-100 reactor demonstrations, as well as other technology developments. At the time these awards were competed, advanced reactor applicants were at the Class 5 stage. As these multi-year public-private partnerships mature toward construction, cost variations based on PCE refinement are to be expected rather than cause for alarm. Moreover, it can take multiple years and significant resources to detail the supply chain, unit costs, project schedules, and take off needed for a mature PCE. Public-private partnerships are therefore crucial for advanced reactor developers to finance costly early project development.

Licensing

All nuclear reactors in the US must be licensed by the US Nuclear Regulatory Commission (NRC). The licensing process contains many optional steps that developers may take to help speed future applications based on the same design. NuScale showcased this by investing substantially to attain a Standard Design Certification which is used to de-risk future applications by pre-certifying a reactor's technical evaluation. The FOAK license application bears the most risk—and therefore the higher costs associated with technical, regulatory, and legal compliance staff.

Never-before-reviewed designs require consistent early interaction with the NRC to resolve technical hurdles and provide additional information, known as pre-application engagement. Developers spend substantial resources preparing a FOAK application and must also cover the NRC's staff and user fees for these activities. NuScale reportedly paid $70M in NRC fees, plus additional internal costs supporting their application totalling $500M.

Fuel Procurement, Fabrication, and Coolants

Uranium fuel procurement is an upcoming challenge for reactors of all scales. For advanced reactors specifically, the lack of a secure supply chain for high-assay low-enriched uranium (HALEU) leads to broad variance in initial fuel costs for new reactors. This market uncertainty can lead to paying higher prices for fuel contracts or cause costly delays to FOAK projects. After procurement, fuel must be "fabricated" into forms suitable for the reactor type. This requires developers to build additional infrastructure or source this capacity from a limited set of vendors. X-energy is in the process of working with the DOE to construct the first commercial HALEU fabrication facility in the US. Similarly, Kairos Power has invested commercial capacity to produce sodium coolant needed for its high-temperature reactors. These activities are all absolutely necessary to bring a FOAK technology to market, but attribute unique supply chain development costs that are overwhelmingly financed by early builds.

Testing

Testing requirements for new advanced reactors are much more substantial as there is less operating and regulatory experience. Therefore, vendors need to spend resources developing testing modules and generating data needed to pass rigorous safety and safeguards requirements. Many advanced reactor companies conduct early product testing with a mix of capital investments in infrastructure and at DOE user facilities, such as the Idaho National Laboratory (INL). TerraPower is currently constructing a test facility in Wyoming for its Natrium technology and has used INL's Advanced Test Reactor to test fuel for the upcoming plant. The US government provides funding to construct and maintain user facilities, however the costs associated with using the facilities are fully attributed to the user through fees.

Success Reduces Costs for Future Builds

Alright, I get the high costs now, but why should the US government continue to support these efforts? Heightened costs for new reactors are a challenge, but are not insurmountable. Repeated analyses show that advanced nuclear will provide tremendous benefits for US communities such as 3,500+ jobs per year and the potential to reshore our domestic industrial base to compete with China and others.

The US has a history of being a world leader in energy technology and then falling into complacency. In 2000, the US controlled 30% of the global market for solar panels to China's <1%. Just two decades later, Chinese companies controlled 70% of the global market for solar technology—the US held <1%.

It's crucial we break this cycle with advanced nuclear. If we make a bold commitment to developing and deploying advanced reactors, we can emerge as and maintain leadership in this critical energy space. Pushing through the pain of FOAK projects enables numerous NOAK efficiencies that would make US companies globally competitive in new reactors for decades to come.

Enduring Early Deployment Makes NOAK Builds More Competitive:

- **NOAK Project Profiles:** Cost estimates and project schedules are more reliable due to demonstrated sourcing in early builds. As order books scale, commercialization is reached and large orders will reduce component costs.

- **Licensing:** Subsequent builds require less application work, as technical and safeguards questions have been settled. This leads to faster reviews and less resources spent on compliance.

- **Fuel:** With developed fabrication capacity, additional expenditures aren't needed until demand scales beyond initial capacity.

- **Testing:** With a demonstrated technology, testing may only be needed for novel changes to a reactor design.

TOPICS

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ENDNOTES

1. Nth refers to a non-specific subsequent build within a model's generation. For new nuclear technology, the US DOE estimates NOAK commercialization may be reached at the 4-6th build of a specific design, based on the technology.