Progress of Early Mover Nuclear Projects: Key Indicators to Watch

Author:
Dr. James Richards, NIA

October 2025

This report is available online at:
https://nuclearinnovationalliance.org/resources

Summary

There are dozens of nuclear projects in various stages of development across the U.S. This document discusses key indicators of progress that investors and key stakeholders can use to assess a nuclear project's likelihood of successful completion.[1] The indicators include site selection, licensing, offtake, project teaming, and funding. These indicators serve as a qualitative evaluation of a project's progress. This paper includes several case studies because each project will look very different, with multiple options to reduce risk within each indicator area.

Introduction

The nuclear energy industry has gone through phases of growth and contraction throughout the 21st century. In the early 2000s, a period that was excitedly referred to as the "nuclear renaissance" took shape in the United States. The U.S. Nuclear Regulatory Commission (NRC) received construction and operating license applications for 30 new reactors between 2007 and 2009. Advanced light water reactor (LWR) designs such as the AP1000 and European Pressurized Reactor (EPR) increased interest in new nuclear energy.

Despite the excitement of the 2000s, a true nuclear renaissance did not materialize in the United States due to unexpected changes in market conditions – most importantly, the abundance of cheap natural gas from improved extraction methods, stagnant load growth and cheap electricity prices. Utilities cancelled nuclear projects and even retired several reactors early for economic reasons. Then the 2011 Fukushima accident in Japan led to more negative public sentiment towards nuclear energy. The nuclear industry contracted through the early 2010s rather than experiencing the expected renaissance.

Currently, there is a resurgence of interest in nuclear energy, driven by decarbonization efforts, reliability concerns, and load growth. Record amounts of venture capital and private equity investments have funneled into nuclear companies;[2] load is projected to grow because of AI, electrification, and manufacturing; and plants that were shut down in the 2010s are being restarted. Incumbent companies and startups are working to commercialize many different nuclear reactor designs with the potential to serve more markets than was previously possible.

There have been a tremendous number of funding rounds, project announcements, and partnership agreements in the last decade, but thus far only two reactors with a new design have come online (i.e., Vogtle units 3 and 4). With all the fervor, it can be difficult to assess the viability of individual projects and to evaluate industry progress. This document discusses several key indicators of progress that stakeholders and investors can use to assess a nuclear project's likelihood of successful completion. Several case studies have been included. These

[1] Note that the information in this document is meant to be a high-level check on the seriousness of a nuclear energy project. This is not investment advice.

[2] See here for more information: [Private equity flows to advanced nuclear companies hit record high in 2024 | S&P Global]

case studies are not exhaustive but are meant to highlight examples of projects that are navigating early mover challenges and opportunities.

Defining Key Indicators of Project Progress

Assessing nuclear energy project risk can be complicated from both technical and business model standpoints. Early-mover projects inevitably face significant project completion risk and that is amplified for nuclear energy projects due to their complexity and the size of the required capital investment. Risk, for the purposes of this document, is any uncertainty associated with a project's start and completion. This could be financial, technical, regulatory, or community acceptance risk.

Different technologies, size classes, use cases, locations, etc. introduce complexities that make each project unique. Despite these differences, several common indicators of progress can be used to quickly assess risk and evaluate confidence in a project's likelihood of success. These indicators include:

Category	**Indicators of Strong Confidence**
Site	• Site selected • Site characterized • Local permits received • Environmental reviews in progress or completed • Civil work on site has begun
Licensing	• Pre-application engagement with the regulator • Submitted license application • Applicant and NRC are consistently meeting regulatory milestones on schedule • Previously awarded construction permit (CP), Standard Design Certification (SDC) or combined construction and operating license (COL) for a given technology
Offtake	• Agreement for firm offtake of material amounts of energy • Corporate commitment to offtake • Approval from public utility commissions for sale to ratepayers, where applicable • Utility and/or regulatory approval of offtake, where applicable
Project team	• Engineering, Procurement and Construction (EPC) contractors selected • EPC or engineering and construction contracts finalized • Major equipment suppliers selected • Long-lead equipment committed • Preliminary design completion • Detailed design completion • Commitments beyond initial deployment (i.e., orderbook)
Funding	• Well-capitalized private and/or public sponsor(s) • Preliminary funding commitments (e.g., LPO conditional commitment, private debt, announced outside investment)

Site Selection

Site selection is critical to any energy project. Site selection reflects a commitment by the project developer, a knowable set of environmental characteristics, and a particular local community. A site can come with beneficial attributes such as access to transmission, robust environmental characterization, co-location with another nuclear plant to share services, or co-location with an offtaker. An announced site also implies that the project sponsor has the legal agreements in place (site ownership or long-term lease) that allow the project to be constructed there, subject to satisfying regulatory requirements.

If done well, site selection also reflects community buy-in, which is important to project success. Local stakeholders can weigh in at many points in the project development process, such as during public NRC hearings or when local environmental permitting or zoning approvals are required. Several nuclear projects encountered roadblocks or were canceled because of poor community buy-in.[3] Recognizing that an unwelcoming community is a tremendous project risk, project developers have focused on locating projects in communities that want them.

Projects that take stakeholders, policymakers, and sovereign tribal nation engagement seriously have a higher likelihood of success. Engaging with the community transparently and early in the process helps developers work with communities to develop trust in the project.

In addition to engagement strategies, understanding and prioritizing local familiarity with nuclear energy or other large energy projects can reduce the risk of project delay. Sites with existing nuclear plants are in communities that are supportive of nuclear energy and would make good candidates for additional units. This can also be true of projects within proximity to Department of Energy National Laboratories, such as Oklo's Aurora project at Idaho National Laboratory

More recently, communities with retiring coal plants have also expressed interest in hosting new nuclear plants.[4] Terrapower's Natrium project is leveraging the existing workforce in Kemmerer, WY, whose economy has been based on coal power generation.[5]

Beyond the stakeholder engagement aspect of site selection, there is project risk when sites have not been announced or procured. The likelihood of project success goes up as the project developers select a site, receive local approvals, complete environmental surveys and ultimately start civil work on the site.

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[3] See Pueblo County drops support for nuclear power after facing backlash from residents as an example of a project that was cancelled because of sentiment.

[4] See Resources for Coal Repowering with Nuclear Energy | NIA

[5] For an review on Terrapower's engagement strategy, see The Power of Engagement | CATF

Case Study: Current Nuclear Sites

Holtec is one of several companies that plan to deploy a nuclear plant at an existing nuclear energy site. Currently, Holtec is refurbishing the Palisades nuclear plant to restart Unit 1, giving the company familiarity with the site and local area. Upon completion of the Palisades restart project in Michigan, the company plans to deploy their SMR-300 design at the same site. This leverages the existing workforce, nuclear expertise, local suppliers, and other potential lessons learned from the Palisades restart project. Additionally, nuclear plant sites already have robust seismic, environmental, and ecological characterization that is required for new licenses. All these factors improve the odds of success for the SMR-300 additions.

Energy Northwest, in partnership with Amazon, is planning to build four X-energy Xe-100 units in Eastern Washington. Public acceptance of nuclear energy in this region is high and local community support for the project is strong, with a Department of Energy National Laboratory, the Hanford nuclear reservation clean-up effort, and the operating nuclear power plant, Columbia Generating Station (CGS), in the area. By placing the reactor at or near CGS, on a site that Energy Northwest owns or has access to and is already zoned for electricity production, the project developer is avoiding many siting challenges.

Even with a robust local nuclear industry, there is still stakeholder engagement work that Energy Northwest will need to do to further reduce completion risk. Legacy nuclear weapons program waste and historical nuclear project cancellations could negatively influence local and state stakeholders. Working with indigenous tribal leaders in the region will also be critical to project success. As the project continues to unfold, tracking the public sentiment will be important to project success.

Regulatory Progress and Approval

In the United States, the nuclear regulatory process can be simplified into three main steps when performing diligence on projects: pre-application, accepted construction permit application (CPA) or Combined License (COL) applications, and awarded permit. Developers that submit a CPA will have to go through an additional application to receive their operating license as construction finishes. There is also a Standard Design Certification (SDC) pathway by which reactor designs can be certified for 15-year periods. A project that uses a reactor with an SDC reduces their regulatory burden significantly.[6]

For early mover projects, pre-application engagement with the NRC is considered best practice. It is important for familiarizing the NRC with a given reactor technology and its safety case, as well as helping the technology developer understand the regulatory process and requirements. "Topical reports" can be submitted to the NRC in which a reactor vendor or project developer can receive feedback from the NRC on specific aspects of design and safety criteria they will be expected to meet. The pre-application phase does not have a set length and does not provide any license itself, which means there is still significant regulatory risk at this stage.

[6] For more on specific licensing pathways, see Nuclear Reactor Licensing 101 | NIA

A developer's submission, and the subsequent acceptance, of a CP or COL application represents a significant step towards regulatory process completion. Shortly after the submission, the NRC does an acceptance review. If the NRC accepts the application, it dockets the review and provides an anticipated completion timeline. The last two CPAs that were docketed by the NRC are scheduled for 18-month review windows. Having an accepted timeline gives some indication as to when nuclear construction may begin. Having the NRC accept a CPA also indicates that the reactor technology design is complete enough for review and a specific site has been chosen.

Once the CPA is approved, construction of nuclear-related components can start. This is a significant milestone that greatly increases confidence that the project will move forward.

The majority of early-mover reactor project developers are targeting the NRC's two-step application process by submitting CPAs and then applying for an operating license at a later date. Project developers working with technologies that have been approved and built previously tend to target the combined license process.[7] Reactor vendors can also pursue a design certification independent of site selection.

Merits of a COL versus a CPA are out of the scope of this paper. For the purposes of understanding licensing risk, progress within the COL or CPA framework is the key metric. When the applications have been accepted by the NRC, and then later awarded, the risk of delay due to regulatory issues is significantly reduced.

Case Study: Kairos Power and Licensing Success

In 2025, Kairos Power announced that they had started nuclear concrete-related pours on their Hermes 1 demonstration unit in Oakridge, TN. This work makes Kairos the first advanced reactor developer to receive a construction permit and then begin nuclear component construction in the United States. In other words, this is the first nuclear construction for a licensed Generation IV reactor design.[8]

To get to that point, Kairos went through the licensing process at the NRC, starting their pre-application engagements as early as 2018 and submitting their Hermes Low-Power Demonstration Reactor CPA in October 2021. Their application review lasted 26 months in total. During pre-application and application phases, there was no guarantee that a license would be given. Receiving the construction permit was a significant milestone that allowed Kairos to enter into firmer agreements with vendors and construction partners.

The Hermes 2 Demonstration Plant, designed to produce electricity, received a construction permit from the NRC in a record 14 months, demonstrating Kairos and the NRC's ability to move faster for subsequent projects. Kairos's in-house licensing expertise, as well as internal NRC familiarity with Kairos's design, should be viewed favorably when evaluating the

[7] For example, see the Fermi America project that will build Westinghouse AP1000 reactors. https://www.nrc.gov/reactors/new-reactors/large-lwr/col/fermi-energy-intel-campus.html
[8] Generation IV refers to nuclear reactors that use coolant other than water, such as high temperature gas reactors, sodium-cooled fast reactors, and molten salt reactors.

potential of future Kairos projects moving forward. Other companies, such as GE-Hitachi, Terrapower and X-Energy, currently have construction permit applications in the review process by the NRC and are looking to replicate this success.

Offtake Agreements

A critical piece of the nuclear project is agreements for purchasing power, also known as offtake. An energy project with a firm contract that has a negotiated purchase price, duration, offtake amount, and right to procure any carbon credit or clean energy certificates significantly improves the project's outlook and ability to close financing. Long-term power purchase agreements (PPA) mean the project's revenue is known for the duration of the PPA. This allows for long-term planning and increases confidence that the developer and investors in the project will receive a return on their investment. In turn, this significantly de-risks the project financially.

Another option for firm offtake is to sell the electricity within a regulated electricity market. A regulated utility can eliminate offtake risk by having a public utility commission (PUC) approve their project and the proposed rate structure at which they plan to sell electricity. A PUC approval is an indicator that the project has little offtake risk.

In terms of project risk reduction, offtake agreements that rely on new technologies will likely include more contingencies than a long-term, firm PPA. In addition, such agreements may be structured to require milestone achievements, offramps, etc. These types of agreements still represent a significant risk reduction. One example is the type of agreement that Google makes to procure energy from a specific technology vendor (e.g., the Master Plant Development Agreement Google and Kairos have entered). Such contracts are not firm PPAs per se, but are explicit precursors to PPAs, subject to further steps in project development.

Non-binding commitments, such as memoranda of understanding, are potentially promising but do not realistically reduce financial project risk. In preparation for or in addition to signing PPA agreements, offtakers can reduce project risk by investing in the project ownership group or in development activities related to the project.

Case Study: Hyperscalers and Large Buyers

In September 2024, Microsoft entered into a 20-year PPA with Constellation to purchase electricity from the Crane Clean Energy Center, formerly named Three Mile Island (TMI) Unit 1. Under this agreement, Microsoft will purchase a significant portion of the 835 MW of carbon-free electricity generated by the plant to power its growing data center operations.

This PPA, Constellation's largest-ever with a single customer, was the critical enabling factor for the reactor's revival. TMI Unit 1 was previously shut down in 2019 because the plant could not recoup its operating costs in the wholesale electricity market in which it operates. Long-term investment in and operation of the plant did not make economic sense at the time because of low prevailing power prices. The guaranteed long-term revenue stream from a Microsoft PPA provided the financial stability necessary for Constellation to invest approximately $1.6 billion to refuel and restart the plant. The reactor is now slated to resume operations by 2028.

By signing this long-term PPA, Microsoft significantly de-risked the project for Constellation. Despite this project being a restart rather than a new build, the arrangement serves as a powerful model for how corporate procurement can directly facilitate the deployment of nuclear energy assets. Other hyperscalers, such as Amazon and Google, have entered into agreements with advanced reactor vendors and project developers to support development activities, announcing their intent to establish offtake agreements once further progress is made in project development.

Project Team

When performing diligence, evaluators should understand (1) who the project developer is, (2) what their specific experience is within the nuclear industry, and (3) what commercial relationships have been finalized.

A project developer is the entity that executes the project and is responsible for project completion. They manage partnerships, contracting, and securing of offtake and financing. The developer generally bears the most risk but then owns some portion of the operating nuclear asset upon completion (the developer may have an agreement to sell the project to another long-term owner on completion, or to continue to own and operate it and sell the output).[9]

Nuclear energy projects could have several different business structures. One option would be for an entity or entities to form a special purpose vehicle (SPV), a type of joint venture with the sole purpose of plant ownership. This method is currently used when project financing other types of large projects and may become common for nuclear energy projects. A project developer will usually take on the management of the SPV and will be responsible for contracting with the engineering procurement and construction (EPC) firm, financing, offtake agreements, etc.

Another project structure option would be for a reactor vendor to act as the project developer. The vendor would not sell a reactor to an SPV or another party; rather, they would negotiate a PPA with the customer and then carry out the rest of the project development activities themselves or with subcontractors. This business model allows the reactor vendor to control more of the process but requires the vendor to develop or acquire the complex capabilities of an experienced project developer. The reactor vendor also needs to be well funded in order to support all the project development activities including licensing and procurement of components with long lead times, and possibly even construction, since PPA payments typically coincide with delivery of electricity.

A third business model would be for a utility (as an off taker) to act as the developer. This structure is usually seen in regulated utility markets with "investor owned" utilities with

[9] For more information on what project developers do, see https://nuclearinnovationalliance.org/new-nuclear-project-development

significant balance sheets. These large utilities are subject to PUC oversight, which can reduce risk relative to SPV or build, own, operate structures with inexperienced developers. The main risk in this model is that the utility must receive state-level PUC approval for project start, funding, and continuation, and must convince the PUC that it has the ability to manage the project risks. The PUC has the authority to halt a project if it does not meet expectations.

In addition to having a capable project developer, project success depends on the capabilities of the project engineer, procurement, and construction contractors (sometimes combined as an EPC contractor). The likelihood of a successful project increases when the contracts are structured so that all parties are incentivized to work together to address complex project issues. Announced agreements with a capable project team are a further indicator of project progress.

Another indicator of a nuclear project's progress is the procurement of long-lead equipment. These are the major components of a nuclear plant that require the longest time to manufacture and deliver, such as the reactor pressure vessel, steam generators, or large forgings. Placing firm orders for these items represents a substantial, often minimally refundable, financial commitment from the developer which signals a high degree of confidence and project maturity.

Additionally, procurement of long-lead items is only possible once the reactor design is sufficiently ready for fabrication, meaning key engineering milestones have been met. Because securing and manufacturing long-lead items directly impacts the project's schedule, having these items committed provides stakeholders with strong evidence that significant financial, design, and timeline risks are being effectively managed.

Case Study: X-Energy, Dow, Energy Northwest and Amazon

X-Energy is developing Xe-100 reactors for projects at two sites: Long Mott, TX with Dow Chemical and Richland, WA with Energy Northwest and Amazon. Both of these projects leverage the expertise of the reactor vendor and the offtake partner to reduce risk via partnership agreements.

In the first project, Dow Chemical is the offtaker and is acting as the project developer. Dow set up a wholly owned subsidiary SPV, Long Mott Energy LLC, as the owner of the nuclear power plant. This structure improves project confidence by leveraging Dow's significant engineering, construction, and project development experience, which is invaluable for a first-of-a-kind (FOAK) project.

In X-Energy's second project, Amazon is the offtaker and expects to purchase power from at least four Xe-100 units. The project is being developed by Energy Northwest, a consortium of public utilities in the state of Washington. Energy Northwest has experience developing and operating power projects in Washington, including the operation of an existing nuclear plant. Amazon itself is also investing substantially in the project, providing $334m for early project development.

Both of these structures increase the likelihood that a project will proceed. Dow and Amazon have demonstrated commitment to the project by organizing the project ownership entity and by putting up capital for project development. These firm commitments raise project confidence more than early and non-binding teaming agreements.

Project Funding

The type and amount of financing that is committed to a project is a major indicator of the project's likelihood of success. Mature technologies generally leverage debt at competitive rates to finance most, or all, of the project, and equity investors in the project make up the remaining financing.

Advanced nuclear technologies, however, are still in the initial phases of commercialization. Commercial debt financing may not yet be feasible for projects with significant cost uncertainty such as new nuclear energy projects. Early mover projects are left with a few options: government funding, equity capital from private investors, or government programs. In reality, the first few projects of a given technology will likely require some combination of funding sources.

Companies that are well funded are better positioned to deploy nuclear energy projects. This could be private companies who have raised large amounts of private capital. With total equity investments in their company totaling over $1b, there is more confidence that Terrapower will be able to fund the project than a typical earlier-stage startup. Public companies can also leverage the capital they receive via stock offerings. Oklo, NuScale, and Nano nuclear, for example, went public via Special Purpose Acquisition Companies (SPAC) and have seen massive gains in stock price. Both the capital raised during the public offering process and the implications for better lending rates when a company's market cap increases can be helpful for funding projects.

Government funding can be an important tool for funding these new projects. The DOE Loan Programs Office provides debt financing for projects using innovative technologies, including nuclear energy, and may be critical for the first few new nuclear energy projects. Private equity capital, loan guarantees such as those from LPO, and public grants such as those provided by the DOE's Advanced Reactor Demonstration Program should inspire confidence in the project when evaluating early-mover and fast follower nuclear energy projects' funding.

Project financial risk is greatly reduced when funding is secured.

Subsequent Projects and Orderbooks

Even with strong project planning, it may be difficult to achieve high confidence in the key indicators described in this paper for a first-of-a-kind (FOAK) project. For example, debt financing may not be available for early projects, or the design may need to change during project construction because unforeseen issues arise.

However, once the first project of a given technology is completed, the risk to the second project drops significantly. EPC partners become more familiar with building the reactor technology, financiers have evidence that projects can be completed, the NRC has demonstrated their ability and willingness to license the reactor design, and issues with the technology that were uncovered during the build process can be worked out. The more units of the project's technology have previously been built, the more confidence there is in the project.

Project developers can take advantage of orderbooks to derisk projects even prior to first-of-a-kind (FOAK) deployment. An orderbook, or simply firm contracts for the sale of multiple reactors, generally in series, can leverage the reduction in project risk from one project to the next by spreading risk and learning across multiple sequential projects. The developer gets clear commitments from the offtaker that there is a market for many reactor units, and the offtaker(s) gets to reap the benefits of increased efficiency and learning.

Because an orderbook provides commitment for the second project and beyond, a project developer can negotiate partnerships with vendors or EPCs for longer-term contracts and improved costs that reflect the expectation of risk reductions across projects.

It is important to note that an orderbook requires some amount of firm commitment from the offtaker(s) in order to maximize confidence in FOAK and subsequent project success. This could be in the form of signed PPAs, down payments, or reactor orders. Non-binding commitments or commitments where the offtaker does not bear any risk do not materially improve project outlook.

Case Study: Google and Kairos

Google and Kairos entered into a Master Plant Development agreement in October 2024. This agreement, while not focused on a single site, paves the way for up to 500 MW from Kairos reactors to power Google datacenters and infrastructure by 2035. The power will be procured via PPAs.

The first PPA to come from this agreement was signed in August 2025 for Google to purchase power from the 50 MW HERMES 2 reactor in Oakridge, TN. The PPA, also in partnership with the Tennessee Valley Authority, serves as the first tranche of the larger deal.

The master agreement is currently the closest agreement to a full-fledged orderbook. Milestones were developed in the contract so that opportunities are unlocked as Kairos demonstrates competency. This, in turn, creates confidence within the financial community because the technological risk is reduced with each milestone, the offtake risk is minimized for each individual project, and the reactor licensing burden is known and reduced via previous project learning. The Master Plant Development contract means that every new reactor will build on the learnings from the last reactor project.

Conclusion

The renewed enthusiasm for nuclear energy has generated a significant number of project announcements, partnerships, and funding rounds. While this momentum is positive, it can also make it difficult for stakeholders to differentiate between projects with a high likelihood of success and those that remain in preliminary, high-risk stages. The key indicators outlined in this report - site selection, licensing progress, offtake agreements, project team, and funding - provide a structured framework to evaluate a project's true progress.

A crucial theme across these indicators is the distinction between non-binding intent and firm commitment. A secured site with community support and local government approvals, a docketed license application with a clear review schedule, a signed long-term PPA from a creditworthy offtaker, a finalized EPC contract with an experienced partner, and committed orders for long-lead equipment are all tangible milestones that represent significant de-risking. These actions provide far more confidence in a project's future than preliminary memoranda of understanding or teaming agreements.

Successfully navigating these milestones is most critical for FOAK projects, which carry the highest risk but also pave the way to a mature industry. The lessons learned and experience gained from a successful FOAK deployment, from licensing efficiencies to supply chain performance, can be replicated to lower the cost and risk of subsequent projects. This is why the development of multi-unit orderbooks is so important: it creates a synergistic cycle where commitment to a series of plants helps de-risk the first one.

Ultimately, by applying this disciplined, indicator-based approach, stakeholders can effectively assess the maturity and viability of any nuclear energy project. This framework enables investors, policymakers, and customers to identify and support projects that are most credibly positioned to successfully deliver the next generation of reliable, clean, nuclear energy.