New Nuclear Project Development

Author:
Stephen Greene, NIA

September 2024

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

Executive Summary

Interest is growing in the significant role nuclear energy could play in decarbonizing energy production and improving energy security, with an increased focus on what it takes to bring a new nuclear energy project to fruition. This paper describes the key responsibilities that need to be fulfilled during the development of an energy project, the challenges to development of nuclear energy projects, and potential solutions. The paper seeks to clarify expectations for new nuclear energy project development and enable stakeholders to understand how the risk allocation for the next few nuclear energy projects may need to be different from that of energy projects with more established technologies and greater construction experience.

Energy project development requires fulfilling many roles, including:

- Project developer – manages siting, permitting and licensing, community engagement, economic analysis, financial structuring, and most importantly, identifying the other project participants and negotiating agreements with them
- Customers for energy offtake
- Engineering, procurement, and construction contractor(s)
- Equipment suppliers and technology licensors
- Operators
- Equity investors and lenders

Many organizations with experienced project management organizations, including electric utilities and large industrial companies, may be able to effectively develop energy projects. Independent energy project developers, similar to those that have developed many fossil-fired and renewable energy projects, may serve a valuable role through disciplined risk management and the opportunity to leverage experience with multiple projects and a variety of situations. However, independent project developers have historically not developed nuclear power plants. Three key factors make independent development of new nuclear energy projects more challenging than other types of energy projects:

- Large capital requirements
- The project development (pre-construction) timeframe is longer, and the cost is greater, than for projects using currently prevailing energy technologies
- Due to the limited commercial maturity of advanced nuclear technologies and the dearth of recent construction experience, supply chains and construction capabilities are limited, and it is more difficult to allocate risks efficiently for a

nuclear energy project today than it is for projects using more established energy technologies

To be able to move forward on advanced nuclear energy projects despite the limited experience with the technologies and construction, other parties such as public utilities, industrial customers, and governments will need to step up and agree to take on key elements of project risk. In particular:

- Sponsors and offtakers, such as public utilities and industrial customers, may need to provide additional support for development due to the cost, time, and risk.
- Successful financing is likely to require sponsors and offtakers to backstop some part of project costs, at least for the first few projects of a given technology.
- Policy changes to reduce the cost of nuclear energy project development would also reduce the risk inherent in project development, facilitating more potential projects. A key area to improve is the cost and time required for licensing. Current NRC reform efforts and the ADVANCE Act are promising steps to improve the licensing process, but more actions should be considered.
- Additional government support to backstop project risk would accelerate the development and deployment of nuclear energy projects.

Introduction

Interest is growing in nuclear energy as one of the key solutions to decarbonize energy production and to improve energy security. As a result of that interest there is also an increased focus on what it takes to bring a new nuclear energy project to fruition. This paper describes the main roles and responsibilities that need to be fulfilled during the development of an energy project and the challenges to development of new nuclear energy projects due to the current commercial status of the technologies and the limited recent experience with their construction. The discussion is applicable to development in both price-regulated and restructured markets for power, as well as to behind-the meter projects, though the details will vary. The paper seeks to clarify expectations for the development of nuclear energy projects so stakeholders can proceed with an understanding of how the risk allocation for the next few nuclear energy projects may need to be different from that of energy projects with more commercially mature technologies and greater construction experience.

Project development for an energy project involves investing in, coordinating, and executing a range of activities from site selection and control[1] through licensing, engineering, negotiating offtake agreements,[2] and arranging financing; these steps are needed to position the project for construction and operations. Historically, large nuclear generating projects have been developed by utilities or public entities that earn revenue through electricity sales to retail customers, at rates subject to oversight by a Public Utility Commission or other government entity. That differs greatly from much recent development of other power generation projects, both renewable and fossil-fueled, which has been performed by independent project developers, who develop projects to sell the output to utilities or other wholesale or industrial buyers (or in some cases, develop and sell the projects to other owners).

Technological advances now offer the possibility of developing nuclear power projects of a variety of sizes and capital requirements. At the same time, traditional utilities have so far been reticent to commit to new nuclear power projects due in part to the amount of capital involved and the perceived financial risk.[3] This paper looks at the requirements of project development for a nuclear energy project.

What roles must be filled in a project?

An energy project such as a nuclear energy generation unit requires parties to fill a wide range of roles. These include (also see Figure 1):

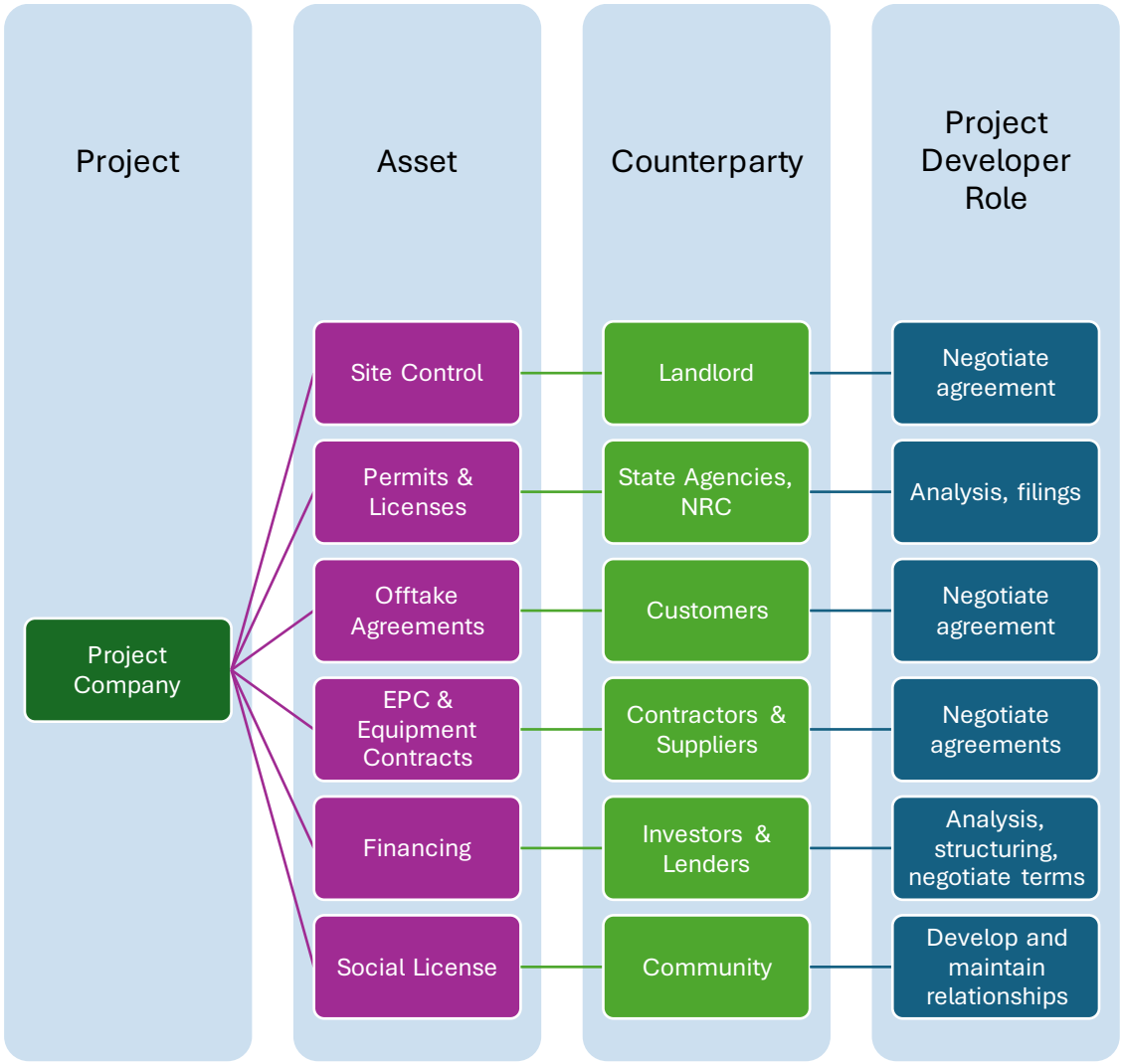
- Project developer – typically puts the pieces of the project together, and invests in and carries out the initial project development work, including:[4]
    - Finding, evaluating, and controlling a site (e.g., through an option to purchase or lease)
    - Permitting and licensing, including substantial analysis that requires expenditures for outside firms. Licensing a nuclear energy unit today requires significantly more up-front expense than permitting processes

[1] "Site control" means establishing a legal right to use the site for the intended purchase, through a lease, purchase, or (more commonly in early stages of a project) a legally binding option to lease or purchase.
[2] For projects developed by price-regulated utilities, such agreements are not needed if the utility will use all the offtake, but such projects will need to obtain regulatory approval.
[3] The NIA explored challenges to nuclear energy project development and potential solutions in its recent report, "Catalyzing Commitments to Advanced Nuclear Energy Projects," June 2024, https://www.nuclearinnovationalliance.org/catalyzing-commitments-advanced-nuclear-energy-projects
[4] To be successful, project developers need to have the skills and expertise to conduct or manage all of this work, in particular, managing permitting, licensing, financing, and construction. Typically, developers, even including regulated utilities, cannot recover the cost of development unless the project proceeds to construction, so developers expect to be rewarded for success, either through explicit fees or returns on investment.

for more established types of energy production (as discussed further below).
    - Community engagement
    - Economic analysis and financial structuring
    - Interconnection agreements if the project will be sending power to the grid
    - Selecting parties for all the roles below, and negotiating agreements with them
- Customers for the energy offtake, who could be utilities or industrial or commercial customers
- Engineering, Procurement, and Construction (EPC) contractor, or separate engineer and constructor
- Major equipment supplier(s) and/or technology licensors[5]
- Other equipment, material, and service suppliers
- Operators, who could be affiliated with the sponsor or offtaker, or who could be contracted (nuclear reactor operators must be licensed by the NRC)
- Equity investors
- Lenders and providers of other types of credit
- To carry out the tasks described above, the project developer will also interact with:
    - The federal Nuclear Regulatory Commission (NRC), which licenses and regulates civilian nuclear energy
    - State and local permitting agencies
    - Federal, state and local tax agencies
    - State and local economic development organizations
    - Regulators, in the case of a project being developed by a price-regulated utility

[5] Technology licensors provide a license, or right, for a project to use a technical design (not to be confused with the license to operate a nuclear facility that must be obtained from the Nuclear Regulatory Commission).

Figure 1: Project Development Responsibilities



Some of the nuclear energy projects currently in development offer examples of how these roles are being fulfilled:

- Kemmerer, Wyoming (TerraPower/Natrium)
  - TerraPower is the developer of the project
  - Rocky Mountain Power (PacifiCorp) will be the offtaker
  - TerraPower has selected Bechtel to be the EPC contractor, performing engineering/design, procurement, and construction[6]
- Darlington, Ontario (Ontario Power Generation [OPG])
  - OPG has selected SNC-Lavalin to provide engineering, Aecon for construction, and GE-Hitachi for the reactor technology and for

[6] Bechtel, "America's Next Nuclear Power Plant Begins Construction," June 10, 2024, https://www.bechtel.com/newsroom/press-releases/americas-next-nuclear-power-plant-begins-construction/

procurement, and has signed a joint agreement with these companies for integrated project development[7]
    - OPG will be the offtaker
- Seadrift, Texas (Dow and X-energy)
    - Dow and X-energy are developing the project under a joint development agreement[8]
    - Dow will be the offtaker of steam and power
    - Outside design and construction parties have not been announced, though Dow will likely have significant roles given its experience with large projects

Stages of project development

Fundamentals of project development

If the underlying energy production technology is commercially mature, i.e., it has been fully engineered and previously deployed (which is not yet the case for most new nuclear energy technologies), the basic outline of project development for a nuclear energy project could in principle be similar to that of other large (utility-scale) energy projects. The development, or pre-construction, phase focuses on:

- Finding a site that is suitable from the perspective of the need for power, the ability to deliver the power, access to cooling water, environmental suitability, and community receptivity
- Establishing control of the site, typically through options to lease or buy
- Analyzing the economics of the potential project and negotiating an offtake agreement, as well as beginning discussions with equipment suppliers and construction contractors
- Performing the data collection and analysis needed to apply for environmental and construction permits

Of course, there are variations in these steps, for example if the developer is a price-regulated utility (which will pursue similar steps, some through regulatory proceedings) or the project is primarily for industrial heat energy, but the basic steps are similar.

---

[7] Ontario Power Generation, "Team forms to build North America's first SMR," January 27, 2023, https://www.opg.com/releases/team-forms-to-build-north-americas-first-smr/

[8] Dow, "Dow and X-energy advance efforts to deploy first advanced small modular nuclear reactor at industrial site under DOE's Advanced Reactor Demonstration Program," March 1, 2023, https://corporate.dow.com/en-us/news/press-releases/dow-x-energy-collaborate-on-smr-nuclear.html; https://x-energy.com/blog-all/a-year-of-progress-at-seadrift

A fundamental objective of project development is to bring a project to the point at which an informed decision can be made regarding whether to make the significant financial commitment represented by commencing construction. Doing so requires achieving reasonable resolution of the many elements of a project, such as siting, permitting, and contracts. Project developers also seek to do so with an efficient expenditure of time and money, so if problems are encountered during development and a project cannot move forward, little is lost and the developer can move on to another project.

Developing a nuclear energy project

For a nuclear energy project, even if there were plenty of recent historical examples on which to base construction cost estimates (which in the U.S. is not yet the case given the inconsistent pursuit of nuclear energy since the 1980s), there would be more risk inherent in the development process than for projects using other energy sources. That additional risk is primarily due to the time and cost required to prepare for a nuclear construction license, which requires extensive data collection for seismology, hydrology (for flood-risk analysis), and meteorology (for exposure risk analysis), in addition to the environmental impact, endangered species, and archaeology data typical for most energy and industrial projects. The developer will have to engage an engineering company to prepare a design of sufficient quality for a nuclear construction permit application.

NRC costs. For example, the licensing process for the Kemmerer project will require covering NRC costs of about $12 million and take about 32 months, according to the NRC's estimate[9] and TerraPower's comments (the NRC's generic estimate for the time required to obtain a Construction Permit is 36 months[10]). A rough rule-of-thumb is that applicants will spend about twice the NRC costs to prepare the application and respond to NRC questions, so the total cost to obtain a construction permit is likely to be in the neighborhood of $36 million in addition to the costs associated with reactor design and application preparation. The ADVANCE Act, enacted in July 2024, is expected to decrease licensing costs for advanced reactors, and as more designs go through the process, applicants and the NRC are expected to become more efficient at working together to decrease costs.[11] With focused preparation, it is possible the licensing timeline can be shortened; for example, Kairos Power received a license for

[9] U.S. Nuclear Regulatory Commission letter to TerraPower, LLC, June 12, 2024, https://www.nrc.gov/docs/ML2416/ML24162A063.pdf; NRC staff hours are currently charged to license applicants at $317/hour (https://www.govinfo.gov/content/pkg/FR-2024-06-20/pdf/FR-2024-06-20.pdf).
[10] U.S. Nuclear Regulatory Commission, "Generic Milestone Schedules of Requested Activities of the Commission," https://www.nrc.gov/about-nrc/generic-schedules.html
[11] Office of Nuclear Energy, "Newly Signed Bill Will Boost Nuclear Reactor Deployment in the United States," July 10, 2024, https://www.energy.gov/ne/articles/newly-signed-bill-will-boost-nuclear-reactor-deployment-united-states

their Hermes test reactor in about 26 months.[12] The NRC and others are exploring approaches to reduce the time and cost required for licensing, with a particular focus on licensing multiple projects with the same technology.[13]

Supply chain. In addition, since there has been little recent construction of nuclear projects in the United States, the supply chain for nuclear equipment is limited, and developers may need to take on further risk by making supply commitments before a construction permit has been obtained. Building a series of projects using the same technology would allow the supply chain to scale and reduce the commitment required for individual projects.[14]

Risks for project developers. The lengthy timeframe and high cost of the development effort raise the stakes for developing a new nuclear energy project compared to more established types of energy projects. Of course, there are many potential rewards for that development effort: 24/7 production independent of weather conditions, less dependence on location than renewable energy (and therefore likely lower requirements for transmission investment), and suitability for industrial thermal energy requirements, to state just a few. However, project developers and investors may seek a balance for the greater risks during the development period through higher offtake pricing, stronger commitments from offtakers, and risk-sharing arrangements with other parties.

Project development timeline

The expected timeframe to bring a nuclear energy project to fruition is uncertain given inconsistent recent experience and the variety of new advanced nuclear technologies being pursued. However, the experience to date and the projected timeframes for projects currently in the licensing process can provide some insight, recognizing that the technologies, size, and other project characteristics may lead to different timelines for different projects.

To provide a rough, illustrative view of current licensing timelines, Figure 2 shows approximate timelines for the Darlington and Kemmerer projects based on several

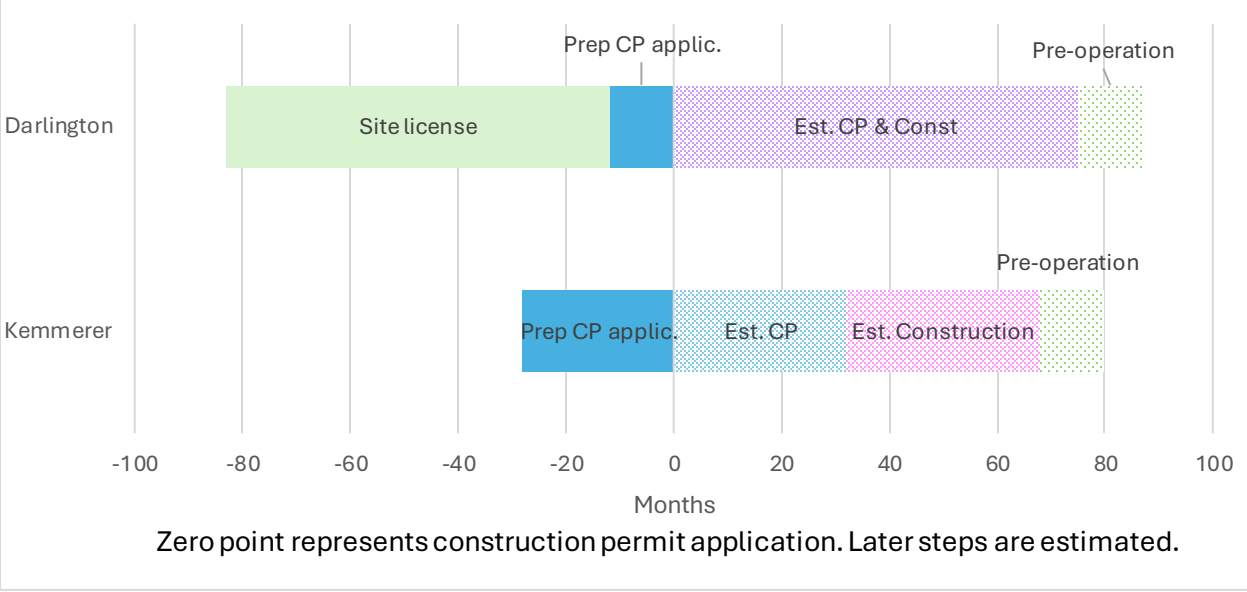
[12] This is not a commercial reactor, but the expeditious permitting still indicates potential efficiencies with broader applicability. See: U.S. Nuclear Regulatory Commission, "Hermes – Kairos Application," https://www.nrc.gov/reactors/non-power/new-facility-licensing/hermes-kairos.html

[13] See Nuclear Innovation Alliance, "Enabling High Volume Licensing of Advanced Nuclear Energy," January 31, 2024, https://www.nuclearinnovationalliance.org/enabling-high-volume-licensing-advanced-nuclear-energy and Nuclear Energy Institute, letter to U.S. Nuclear Regulatory Commission, July 31, 2024, https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML24213A337

[14] For example, see U.S. Department of Energy, "The pathway to: Advanced Nuclear Commercial Liftoff," March 2023, https://liftoff.energy.gov/advanced-nuclear/

sources from the companies and regulatory agencies.[15] The construction license application for Darlington was submitted in October 2022, and the construction permit application for Kemmerer was submitted in March 2024; dates beyond that point are estimates from the companies or the respective regulatory authorities (NRC in the case of Natrium, and the Canadian Nuclear Safety Commission [CNSC] in the case of OPG). The historical timing for Darlington is complicated because the project was on hold for several years after the site license was originally approved in 2012 (that delay is excluded from the timeframes shown below).

Figure 2: Indicative development timelines[16]



Zero point represents construction permit application. Later steps are estimated.

Who is a project developer?

Through the 1970s, public utilities (typically regulated at the state level) developed and constructed almost all electric power generation. The Public Utility Regulatory Policies Act (PURPA), enacted in 1978, allowed entities other than public utilities – independent project developers – to sell power from cogeneration facilities and facilities using certain types of renewable generation. The Energy Policy Act of 1992 and subsequent rulemaking by the Federal Energy Regulatory Commission (FERC) and state commissions broadened market access for independent project

[15] This graphic provides only a rough, illustrative overview. There are many details not shown here that could work out differently for other projects. In particular, we note that the licensing processes for the NRC and the Canadian Nuclear Safety Commission are different. The estimate for pre-operation is based on a range of historical data and inference, and could vary greatly depending on the technology and the maturity of design.
[16] Darlington construction permit (CP) application preparation estimated from date of site license renewal. Kemmerer CP application preparation estimated from date of site announcement. See previous footnote regarding assumptions and simplifications.

developers, and set the stage for them to become responsible for developing and constructing most of the new power generation in large parts of the United States.[17]

Technology Developer ≠ Project Developer

For projects being commercially developed, usually the technologies have already been fully engineered and are supported by an equipment vendor. The current situation with nuclear energy is different, with many new nuclear energy technologies seeking to be incorporated into commercial projects. For that reason, some technology developers are also seeking to be project developers, at least for the initial projects involving their technologies. To be successful, these technology developers will need to acquire the expertise to manage the many aspects of project development described above. Furthermore, they will need to decide whether they will continue to play that role for the long term or how they will extricate themselves from that role for future projects. Finally, they will need to manage their investors' expectations regarding their ability to succeed as a project developer and to manage the risks associated with project development.

Many organizations with experienced project management teams, including electric utilities and large industrial companies, may be able to effectively develop energy projects. Independent energy project developers, similar to those that have developed fossil-fired and renewable energy projects, could serve a useful role through disciplined risk management and the opportunity to leverage experience with multiple projects and a variety of project situations. Independent developers could either develop a project and sell the energy, or could sell the project once it is completed to another owner, such as a utility. However, independent project developers have historically not developed nuclear power plants. To some extent that is because the changes in policy enabling independent power project development coincided with the availability of efficient combined-cycle gas-fired generation and state and federal incentives for renewable energy.

Three key factors that make independent development of nuclear energy projects more challenging than other types of energy projects are:

- **Capital requirements:** the capital required for a traditional gigawatt-scale nuclear power plant is far greater than that required for a typical independent power project. Small modular reactors and micro-reactors potentially provide an opportunity to develop nuclear power projects with smaller total capital commitments.

[17] U.S. Federal Energy Regulatory Commission, "Electric Competition," https://www.ferc.gov/industries-data/electric/power-sales-and-markets/electric-competition

- **Project development timeframe and cost:** projects make money when they start operating. As described above, the long timeframe of development and the higher cost outlays in the pre-construction phase affect any project developer, but particularly independent developers who typically have higher costs of capital, at least until project construction begins. NRC licensing process improvements and faster construction times that may be achievable for smaller reactors could mitigate this challenge.
- **Project risk management: *this is the key issue hindering independent development of nuclear energy projects today.*** Independent developers succeed by managing the project development process efficiently and orchestrating the relationships between other project participants, identifying key risks and assigning each to a party that can best manage it, and has the financial resources to backstop their responsibilities. In a typical independent power project, much of the risk related to cost of construction, delay of completion, and project performance is allocated to the EPC contractor. EPC contractors will be reticent to take on the risk for advanced nuclear generation until there is more experience with the designs, as described in the box below. But independent project developers don't have the risk tolerance or financial resources to accept that risk themselves. ***The key question is which parties have the motivation and resources to manage that risk for the first few advanced nuclear energy projects.***

Who takes project construction and performance risk?

A key difference between a typical non-nuclear power project and today's nuclear power projects is the framework for managing construction risk. As an example, for a typical power project, an equipment vendor provides key generation equipment, such as a wind turbine or gas turbine. That equipment has been fully tested by the manufacturer and comes with performance guarantees. The project construction is much less complex than for a nuclear power plant and the constructor typically has substantial experience with what is being built. Because of that, an EPC contractor is typically willing to provide a fixed-priced construction agreement with a "wrap" of vendor guarantees, meaning they will incorporate the equipment vendors' guarantees into their own, with guarantees for timing of project delivery and performance.

Contrast that with a new advanced nuclear energy project for which there may be little to no experience constructing the design, the supply chain is yet to be developed, and the technology licensors have limited credit to support guarantees. In that scenario the project developer will be challenged to obtain meaningful control of price, completion timeframe, and performance from an EPC contractor.

To be able to move forward on advanced nuclear energy projects despite the limited experience with the designs, other parties will need to step up and agree to take on the key elements of risk. Parties who might see the value of doing so may include:

- **Public utilities.** Few public utilities have been willing to make commitments to new nuclear energy projects since the 1980s.[18] The risk is that either the utility's customers could be asked to absorb unplanned costs, with the associated economic and political repercussions, or the utility's shareholders could end up absorbing additional costs. However, there is tension between that risk and the commitments many utilities and state governments have made to decarbonizing energy systems, which much analysis shows will require substantial increases in nuclear energy.[19] In addition, there is recent recognition that electric power demand may grow more rapidly than in the recent past, and that new firm, zero-carbon energy supply such as nuclear energy will be critical to meet that demand without investing in additional CO_2-emitting assets.[20] Utilities and their regulators should consider the value that the recently completed Vogtle units, even with their challenges, have brought to the region, with substantial interest in new industrial development resulting from the availability of firm zero-carbon power. Utilities could make a greater commitment to new nuclear projects either by developing projects on their own, or by partnering with independent project developers (if they don't have recent large-project development experience or want to leverage outside capabilities) and providing additional support for project risks. Groups of utilities could share early-mover risks by creating consortia to build fleets of units. So far, the tension has simply been allowed to build, with all parties waiting for "someone else" to take the risk first.
- **Industrial customers.** Many energy users have made or are considering commitments to decarbonize their energy supply and recognize that nuclear energy may be a key tool to meet those commitments, and in some cases (e.g., for datacenters) to supply energy to meet growing demand. For example, the Dow Seadrift project would supply a chemical plant in Texas, and Amazon has committed to purchase nuclear energy for a datacenter in Pennsylvania.[21]

---

[18] Some utilities are moving forward, for example, Ontario Power Generation (OPG), which has historically had a strong commitment to nuclear energy. Georgia Power and its co-sponsors maintained their commitment to nuclear power even in light of the difficult challenges to the Vogtle project.

[19] See, e.g., World Nuclear News, "Granholm calls for tripling of US nuclear fleet," June 7, 2024, https://www.world-nuclear-news.org/Articles/Granholm-calls-for-tripling-of-US-nuclear-fleet

[20] See, e.g., S&P Global, Load growth, Vogtle boost nuclear's prospects, but utilities seek more support," June 10, 2024, https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/load-growth-vogtle-boost-nuclear-s-prospects-but-utilities-seek-more-support-81976035

[21] POWER Magazine, "X-Energy, Dow Unveil Texas Site for ARDP Nuclear Demonstration," May 11, 2023, https://www.powermag.com/x-energy-dow-unveil-texas-site-for-ardp-nuclear-demonstration/ and World

Some industrial customers may continue to develop their own energy supply, including nuclear energy, while others may prefer to purchase supply from utilities or independent developers in the future. Industrial customers may conclude that it is to their benefit to provide a backstop for the cost and performance risks for initial projects (with appropriate rights to review and participate in major decisions) in order to accelerate the deployment of advanced nuclear energy to address their energy requirements and decarbonization objectives.

- **The U.S. government, and potentially state governments.** As noted above, deploying more nuclear energy production is critical to decarbonization efforts and to meeting growth in electric power demand without committing to additional CO_2-emitting assets. Doing so will also reduce dependence on world fossil-fuel markets that will continue to be influenced by actions of foreign governments, including Russia. Thus, the U.S. government and state governments have an interest in supporting the initial deployments of advanced nuclear energy projects, and should consider mitigating part of the cost and performance risk for those projects, for example through additional funding and assuring project completion.

Conclusion

Interest in expanding nuclear energy production is growing. However, the next few nuclear energy projects will involve more development and financial risk than development of fossil-fired or renewable energy projects for which the technologies and development processes are more mature (in part resulting from decades of policy support).

Many parties have the opportunity to pursue development of advanced nuclear energy projects, and over time such project development can become an efficient process. Initially, however, parties with the resources and motivation to support the nascent opportunities for advanced nuclear energy development will need to help those developers mitigate the cost, timing, and performance risk that is an unavoidable element of early mover projects. NIA's paper, *Catalyzing Commitments to Advanced Nuclear Energy Projects*, provided recommendations for steps to reduce project risk and help developers manage that risk, including:[22]

- Potential private-sector actions

Nuclear News, "Talen sells carbon-free data centre to Amazon cloud company," March 5, 2024, https://www.world-nuclear-news.org/Articles/Talen-sells-carbon-free-data-centre-to-Amazon-clou

[22] Nuclear Innovation Alliance, "Catalyzing Commitments to Advanced Nuclear Energy Projects," June 2024, https://www.nuclearinnovationalliance.org/catalyzing-commitments-advanced-nuclear-energy-projects

    - Sponsors and offtakers may need to provide additional financial support for development due to the cost, time, and risk.
    - Successful financing is likely to require sponsors and offtakers to backstop some part of project costs, at least for the first few projects of a given technology.

- Potential public-sector actions
    - Policy changes to reduce the cost of nuclear energy project development would also reduce the risk inherent in project development, facilitating more potential projects. A key area to improve is the cost and time required for licensing. Current NRC reform efforts and the ADVANCE Act[23] are promising steps to improve the licensing process, but more actions should be considered.[24]
    - Additional government support to backstop project risk would accelerate the development and deployment of nuclear energy projects.

[23] U.S. Nuclear Regulatory Commission, "ADVANCE Act (Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act of 2024)," https://www.nrc.gov/about-nrc/governing-laws/advance-act.html
[24] See, e.g., Judi Greenwald, "The Urgency of NRC Reform," July 2024, https://nuclearinnovationalliance.org/urgency-nrc-reform