Blueprint for Consideration of Advanced Nuclear Energy Technologies

January 2025

NEW YORK STATE

NYSERDA
New York State Energy Research
and Development Authority

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Acronyms and Abbreviations

ARDP	Advanced Reactor Development Program
BOAK	between-of-a-kind
Climate Act	New York State Climate Leadership and Community Protection Act
DAC	disadvantaged community
DEFRs	Dispatchable Emissions Free Resources
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
FOAK	first-of-a-kind
Gen II	Generation 2
Gen III	Generation 3
Gen IV	Generation 4
GW	gigawatt
HALEU	high-assay low-enriched uranium
HEU	high-enriched uranium
HTGR	high-temperature gas reactor’
ITC	investment tax credit
kW	kilowatt
kWh	kilowatt hours
LEU	low-enriched uranium
LWR	light water reactor
Master Plan	Master Plan for Responsible Advanced Nuclear Development
MW	megawatt
NOAK	Nth-of-a-kind
NRC	Nuclear Regulatory Commission
NYISO	New York Independent System Operator
NYS	New York State
NYSERDA	New York State Energy Research & Development Authority
PTC	production tax credit
R&D	research and development
RFP	request for proposal
SFR	sodium-cooled fast reactor
SMR	small modular reactor
TRISO	tristructural isotropic
ZEC	Zero Emission Credit

1 Introduction: Potential Role of Advanced Nuclear Technologies in New York's Energy Future

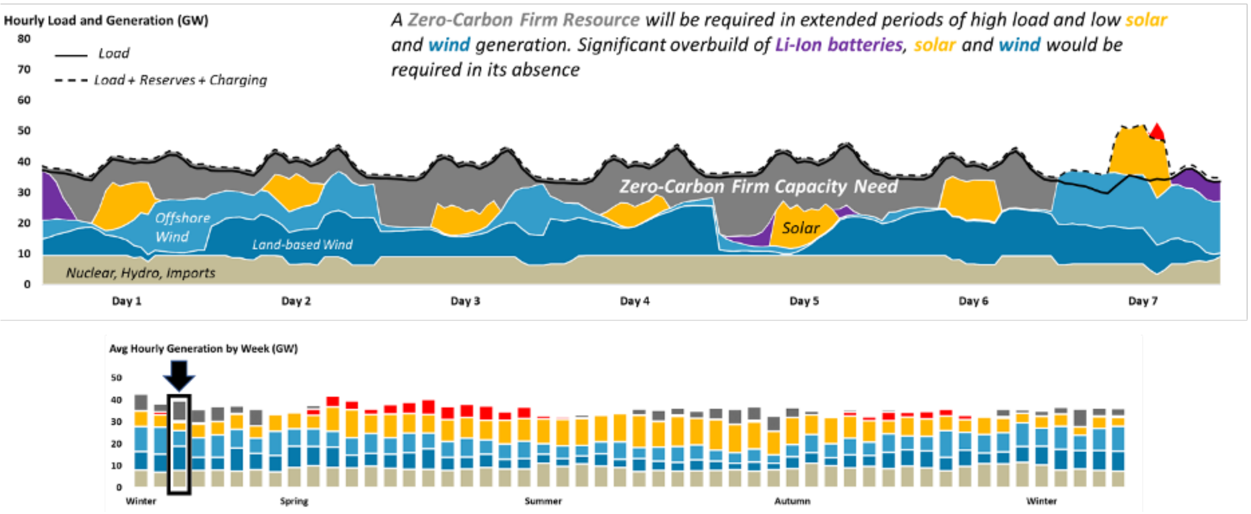
A clean, reliable, and affordable energy system is critical to the future of New York's economy and the health and prosperity of all its citizens. To realize that future, the Climate Leadership and Community Protection Act (Climate Act) directs the Public Service Commission (Commission) to ensure that the statewide electrical demand system is "zero emissions" by 2040 (0×40) and directs all State agencies to pursue a carbon-neutral economy by 2050.[1]

The State is on its way to meeting these objectives through increases in distributed and centralized solar energy, wind power, energy storage, and other measures, through ongoing proceedings before the Commission, which also provide opportunities for public input into future decision making. The Commission has not adopted a definition of "zero emissions," but, in the 2016 order through which it established the Zero Emission Credit (ZEC) program, the Commission characterized existing nuclear generation as a zero-emission technology. Staff of the Department of Public Service published a white paper with further specifics on proposed definitions of zero-emission technologies in November 2024.[2]

Nonetheless, studies identify a critical need in the path to a zero emissions grid in New York: controllable clean electricity technologies that can reliably meet the demand for power throughout the year, even when onshore and offshore wind and solar energy are less available. The New York Independent System Operator (NYISO) refers to these technologies as Dispatchable Emissions Free Resources (DEFRs). Figure 1 from the Climate Action Council's analysis of a fully decarbonized electric system illustrates this need across several simulated days; the need is most pronounced during prolonged periods of low solar and wind output.

Figure 1. Need for Zero-Carbon Firm Capacity in a Decarbonized New York Grid in 2050

Sources and Notes: Figure is from the New York State Climate Action Council Scoping Plan Appendix G: Integration Analysis Technical Supplement New York State Climate Action Council Scoping Plan, section I - Page 50.



New York's need for DEFRs will increase as demand grows, as fossil-fired dispatchable resources are phased out, and as the 2040 and 2050 deadlines approach. The Climate Action Council's analysis shows that the State will need approximately 20 gigawatts (GW) of dispatchable clean power to complement the wind and solar resources on the system by 2050.[3] Similarly, the NYISO forecasts even larger requirements for decarbonized firm resources, identifying needs that extend beyond 25 GW statewide by 2040 and exceed 40 GW in some scenarios.[4]

Along with increased energy efficiency and load flexibility, a number of technologies are advancing to meet this need. A partial list of these options includes advanced geothermal power, long-duration storage, and green hydrogen. This is highly positive, as it is unlikely that a single technology will emerge to meet this large, critical need.

In addition to these options, a growing and innovative group of advanced nuclear energy technologies as recently emerged as a potential source of dispatchable carbon-free power.[5]

The term "advanced" is used to refer to this suite of technologies simply to distinguish these new designs from the majority of existing nuclear plants in the U.S. built primarily decades ago. Advanced nuclear technologies offer attractive possibilities, with their scalability, economic development, low land use, advanced operational (including safety) features, and potential applications for process heat. These technologies may represent an opportunity for additional grid capacity to support an electrifying economy that can both complement New York’s buildout of renewables and serve as a baseload resource unto itself. The potential of advanced nuclear is highlighted in the U.S. Department of Energy’s “Pathways to Commercial Liftoff: Advanced Nuclear report and federal support for new nuclear development,” with the passage of the ADVANCE Act in 2024, which reduces licensing fees and streamlines Nuclear Regulatory Commission (NRC) regulatory processes with the goal of accelerating deployment timelines.[6]

Yet advanced nuclear technologies raise a host of questions, regarding technological readiness, environmental and climate justice, waste, cost, and cost risks, among other factors.

This Blueprint provides an initial inventory of the range of these issues as the starting point for an in-depth follow-up assessment process that will culminate in a Master Plan for Responsible Advanced Nuclear Development (Master Plan). The objective of this Blueprint is to outline the scope of the most important opportunities, issues, and questions associated with these options, as a platform for such additional analysis and stakeholder input in the Master Plan process. Through this process, the New York State Energy Research and Development Authority (NYSERDA) hopes to move New York forward toward its energy, economic, climate, and equity goals, including an abundant, clean, reliable, and affordable electricity system. The process to develop the Master Plan will take place throughout 2025 and 2026, with a completed Master Plan expected to be published by the end of 2026.

A draft of this Blueprint was published for public comment in September 2024. NYSERDA received comments from a diverse range of stakeholders who offered both robust technical input as well as a broad spectrum of positions both in support of and in opposition to future development of advanced nuclear energy in New York. To the extent pertinent to the objective of the Blueprint as a scoping document, comments have been incorporated in the form of updates, corrections, and expansion of the discussion of issues. Other comments will be utilized in the development of the Master Plan. All comments are available on NYSERDA’s Advanced Nuclear web page.

NYSERDA acknowledges contributions from The Brattle Group in preparing this Blueprint.

2 Profile of Advanced Nuclear Technologies

The profile of advanced nuclear technologies covers issues and considerations including performance profile, land use, modularity, workforce, economic development, and other applications. Considerations also extend beyond the electricity system to include supporting communities and other economic sectors within the state.

2.1 Performance Profile

Nuclear energy generation does not produce direct emissions. From a life-cycle perspective, nuclear reactors have demonstrated the lowest lifecycle emissions of any generation technology.[7] Existing nuclear plants operate continuously when not in a refueling or other outage; the existing U.S. nuclear fleet has been able to operate as “baseload” capacity with over 90% capacity factor. Advanced nuclear technology could similarly serve as a baseload resource. Additionally, advanced nuclear technology is designed to be controllable, and, subject to further examination in future studies, may be able to operate flexibly as a dispatchable clean resource to complement wind and solar resources. In addition to their controllability, advanced nuclear technologies have minimal susceptibility to weather-related events, adding resilience to the electric system.[8] They can also add stability to the grid by virtue of their large, synchronized steam turbines.[9] Thus, as a controllable resource, advanced nuclear technologies could also serve a role as a balancing and regulating resource in a deeply renewable electric grid. Advanced nuclear technologies as a co-located resource to a large commercial, industrial, or manufacturing facility could support significant new economic development due to their ability to supply continuous power and heat to support such facilities while reducing large, localized load to the grid.

2.2 Low Land Use and Modularity

In New York, where land is often at a premium with competing demands for limited space, advanced nuclear technology resources have a very small geographic footprint. For example, nuclear generation uses only about 1% of the land that solar panels would require for a similarly sized system.[10] Such energy density enables plants to be sited near existing grid infrastructure or demand sources even if land is constrained. Moreover, certain advanced reactor designs will not need to be located near sources of water if they use non-water reactor coolants and employ dry cooling for the steam in the steam turbine, further expanding the range of potential sites.

In addition, some advanced nuclear reactors are designed to be “modular” with smaller units that are easier to site and construct, or to expand into larger multiunit plants. Modular design also allows more of the plant to be built in a factory, which could better leverage economies of learning and standardization, reducing the amount of on-site work required and resulting in shorter construction times and lower capital cost and risk.[11]

2.3 Workforce and Economic Development

Although the workforce and economic impacts of advanced nuclear technologies are likely to vary based on the technology type, size, and application, these plants have the potential to provide substantial direct and indirect economic benefits. The construction of advanced nuclear plants has been estimated to create large numbers of high-wage jobs, with a potential for a plant’s construction to employ more than a thousand workers.[12] Thereafter, construction of subsequent plants could extend such employment opportunities over a worker’s career span.

In each advanced nuclear plant’s operating phase, it is estimated that several hundred jobs would continue,[13] with high median salaries for these workers.[14] In addition to providing higher average salaries than available at other electric generating facilities, nuclear plant workers are typically drawn from the existing labor pool in surrounding communities, supporting local job creation. The Nuclear Energy Institute (NEI) has estimated that “for every 100 nuclear power plant jobs, 66 more jobs are created in the local community for people from a wide range of fields and backgrounds.”[15]

If sited as replacement for fossil-fired plants that will be closing or have already closed, new advanced nuclear plants could leverage preexisting transmission connections and replace lost jobs.[16] In one case study, the possible replacement of a 650-megawatt (MW) coal plant with a 925 MW nuclear plant was estimated to create a net increase of 650 full time jobs.[17]

Advanced nuclear technologies may also create opportunities for indirect economic benefits through supply chains, some of which may locate and grow in New York. New York is already home to 32 companies in the nuclear industry, 31 of which also supply the nuclear naval fleet,[18] and hosts nation-leading nuclear education programs.[19] New development in the supply chains would lead to the creation of several hundred additional ongoing jobs and community development in the State.[20]

2.4 Potential Supplemental Applications

Beyond providing firm electric energy and capacity, advanced nuclear plants have a wide variety of applications, including waste heat that could be used for district heating.[21] Some advanced nuclear reactors such as high-temperature gas reactors operate at temperatures that enable them to supply high-quality heat for industries including chemical manufacturing, steel production, hydrogen production, and other high-energy-demand sectors that are difficult to electrify.[22] Hydrogen production in particular is a promising application of all types of advanced nuclear, with one white paper indicating that four different advanced reactor designs could produce hydrogen through high-temperature steam electrolysis.[23] While these use cases could be promising, their applicability to New York's industrial sector would have to be explored and may in some cases require extensive coordination among stakeholders.

3 Overview of Advanced Nuclear Technologies

The technologies discussed in this Blueprint are known as advanced nuclear technologies, which are distinct from conventional reactors operating in the United States today. Today's fleet consists entirely of large light water reactors, which use boiling water or pressurized water as the coolant (to transfer heat for the steam generator and act as a moderator) and which typically generate between 500–1,400 MW.[24] Definitions of what qualifies as an "advanced" nuclear reactor varies, but all advanced options are more recently designed and have features that substantially improve on current operating reactors, incorporating passive or inherent safety systems, other improvements in safety features, modular construction, or versatility in operational capabilities.[25]

A significant design change in many advanced reactors is the use of non-water coolants, which allows safer lower pressures even at higher operating temperatures that increase the efficiency of electricity production, and which changes the nuclear reaction conditions. Water moderates, or slows down, the neutrons in the reactor, which (counterintuitively) increases the likelihood that more fission reactions will occur when neutrons collide with atoms of the isotope uranium-235 (U-235). In the absence of a water moderator, sustaining the nuclear chain reaction requires either (1) adding an alternative neutron moderator, such as graphite;[26] or (2) increasing the concentration of U-235 in the reactor fuel, in what is called a "fast" reactor. Fast reactors use higher-energy neutrons from fission to split both U-235 and U-238 atoms, and thus can extract up to 70 times more energy per unit of fuel than moderated reactors.[27]

Table 1 summarizes the many advanced nuclear plant options both in service and in varying stages of development today in the U.S. and Canada. In this table, new technologies are classified by the coolant cycle they use (top row of Table 1) and by three size ranges for the reactors shown in the rows. Recognizing that some of the terms such as "SMR" and "microreactor" lack fully uniform definitions across the industry, and that modularization and standardization are industry-wide goals not exclusive to smaller reactors, reactor categories are classified here as "large scale" above 300 MW of electric output, "small modular reactors" (SMRs) from 51 to 300 MW, and "microreactors" up to 50 MW.[28] Table 1 refers to nuclear fission technologies throughout, except the final column, which is devoted to fusion reactors. The final row in the table indicates the form of nuclear fuel associated with the coolant cycle in that column.

Nuclear technology discussions also often refer to "generations" of nuclear designs, with current operating reactors – other than the most recently completed reactors Vogtle 3 and 4 – referred to as Gen II or Gen III. The technologies described in this Blueprint are newer "advanced" technologies categorized as either "Gen III+," defined as reactors that offer improved economics and safety over conventional large light water reactors,[29] or "Gen IV," defined as reactors selected by the Gen IV International Forum that offer improved sustainability, economics, safety, and proliferation and will use non-water coolants.[30]

In many of these technology/size categories, there are a number of innovative new companies and designs being developed, each with its own unique features. Recognizing these differences, the categories in Table 1 are nevertheless helpful for grouping the issues that merit further consideration when evaluating these technologies. For example, applications for reactors in the same size classes are typically similar. Large-scale reactors or combinations of co-located smaller reactors are expected to be used for grid electricity and very large industrial sites, including large hydrogen generation sites or data centers. Microreactors could be advantageous for their ease of transport, load-following capabilities, no requirement for water, and flexibility to operate either on or off the electric grid.[31]

Table 1. Advanced Reactor Technology Types and Example Company Technologies

	Water-Cooled Light Water	**Non–Water-Cooled**		**Fusion**
		Liquid Sodium Metal, Molten Salt	**High Temp Gas**	
Large Scale (>300 MW)	Westinghouse AP-1000 (in service)	TerraPower Natrium		Commonwealth Fusion SPARC
Small Modular (51 MW–300 MW)	NuScale VOYGR, GE Hitachi BWRX-300, Westinghouse AP300, Holtec SMR-300	Advanced Reactor Concepts ARC-1000	X-energy Xe-100; General Atomics EM2	
Microreactors (1 MW–-50 MW)		Oklo Aurora Kairos Power KP-FHR	BWXT Ultrasafe Pylon Radiant Kaleidos	
Form of Fuel	Conventional LEU and LEU+	HALEU, TRISO, or other nontraditional forms of uranium-based fuels		Forms of Hydrogen and Helium

Beyond the U.S., three countries—Finland, South Korea, and the United Arab Emirates—are already operating Gen III+ units alongside the two U.S. plants in operation now (Vogtle 3 and 4). In addition, Gen III+ reactors are being developed in the United Kingdom, Canada, and France. Best practices and lessons learned in the development, construction, and operation of these plants is obtainable through dedicated programs operated under the auspices of the Electric Power Research Institute (EPRI), the World Association of Nuclear Operators, and the Institute for Nuclear Plant Operations, among others. Similar forums for collaboration on Gen IV plants have also formed, such as the Gen IV International Forum.[32]

3.1 Light Water Reactors

The first column in the table is for advanced water-cooled, light water reactors (LWRs), which, like the prior generation of reactors, use water as the coolant and low-enriched uranium (LEU) fuel rods as their fuel. Yet advanced LWRs incorporate inherently safer designs with passive control systems that reduce reliance on external power supply or operator intervention for essential accident mitigation functions.[33] Advanced large light water reactors are the only category of reactors on this table that are now fully commercial; Georgia Power has just completed the installation of two units in this category, Vogtle 3 and 4, and is now operating them. Unlike all other reactors in Table 1, the next AP1000s to be built will therefore not be “first-of-a-kind” (FOAK), thus offering the opportunity to leverage initial learnings from the first units, but neither would they be “Nth-of-a-kind” (NOAK) plants that are fully down the learning and cost curves.

Water-cooled SMRs share many design elements with advanced larger light water reactors.[34] SMRs are a size class typically understood to produce between 51 and 300 MW and are capable of being deployed and operated in multiples at a single site.[35] One water-cooled SMR design in the U.S., NuScale’s US600,[36] has received design approval from the Nuclear Regulatory Commission (NRC), a major milestone toward commercial operation, though NuScale has since prioritized an updated design.[37] Several other light water SMRs are in preapplication engagement processes with the NRC, including water-cooled designs by Westinghouse, Holtec, and GE-Hitachi Nuclear.[38] The GE-Hitachi design has been selected by the Darlington project in Ontario, which also features a collaboration with Tennessee Valley Authority to develop a reactor design ultimately certified and installed in the U.S., Canada, and in Europe.[39] GE-Hitachi expects the BWRX-300 at Darlington, ONT, to be operational within the next five years. Westinghouse, the manufacturer of the only commercially operational advanced reactor in the U.S. (i.e., the AP1000 at Plant Vogtle in Georgia), also has an SMR design in development: the AP300. It is possible that some learnings from their manufacture and deployment of the AP1000 will translate to cost reductions in the AP300, and eventually light water SMRs more generally.

3.2 Sodium-Cooled and Molten Salt Reactors

The second column of Table 1 refers to reactors that use some form of molten chemical salt (molten salt reactors) or liquid sodium metal as the coolant (sodium-cooled reactors). Both of these coolants enable certain advantages, such as improved energy production efficiencies due to higher operating temperatures, increased safety due to much lower operating pressures (less than one atmosphere compared to 150 atmospheres in LWRs), and the potential to store energy thermally. Also, both reactor types can be designed as "fast reactors" to increase the energy yield from the uranium fuel.[40] Fast spectrum sodium-cooled and molten salt reactors do not have a moderator, while thermal spectrum reactors with these coolants typically use graphite as a moderator.[41] In addition to these advantages, these reactor types also introduce new challenges discussed in section 4.[42]

The molten salt and liquid sodium reactors in the second column differ from LWRs not only by their coolants and lack of a water moderator,[43] but also by the form of nuclear fuel they consume. Nearly all proposed non-LWR designs use a different type of fuel than the low-enriched U-235 (LEU) fuel rods used in LWRs. While the forms of these fuels vary, most use a form of uranium that is enriched to higher levels of the U-235 isotope called High-Assay Low-Enriched Uranium, or HALEU. The different types of reactors use HALEU in different forms, including zirconium fuel rods and a pebble-like fuel form known as Tri-structural Isotropic particle fuel (TRISO).[44] These new forms of fuel raise a number of supply chain, nuclear waste, and safety issues which are discussed in section 4.

TerraPower's Natrium reactor technology is one example of a sodium-cooled fast reactor.[45] Natrium's construction permit has been submitted to the NRC, but until these reviews are complete, no actual nuclear plant construction can begin. TerraPower has concurrently begun preparation at the site of a coal plant in Kemmerer, WY, that is scheduled to close soon.[46]

In molten salt reactors, which typically use molten fluoride or chloride salt as the primary coolant, the use of molten salt enables dissolving the fissile materials into the coolant so the salt can be heated directly by the fission reaction. Some reactor designs do not dissolve fuel directly into the coolant but use a combination of solid fuel and molten salt coolant. These reactor designs (column 2, rows 2 and 3 of Table 1) are under development in the form of SMRs and microreactors, and several appear to be on track for commercial operation in the 2030s. To cite one example, Kairos Power has submitted a pair of applications for test reactors to the NRC, which are used to verify reactor safety and provide additional experience with new technologies.[47] In December 2023, Kairos received NRC approval for its first 35-MW test reactor in Oak Ridge, TN.[48] This unit, which will not produce electricity, is currently under construction with a targeted completion date of 2027.[49] The NRC issued construction permits for the second unit, the Kairos Hermes 2 test reactor facility, on November 21, 2024.[50] Smaller (15-MW) liquid metal-cooled, metal-fueled fast reactors are also under development by Oklo and aim to achieve commercial operation in the 2030s.[51]

3.3 High-Temperature Gas Reactors

The third column of Table 1 refers to reactors that use gas rather than water, sodium, or molten salt to cool the reactor. Gas reactors operate at higher pressures than sodium and molten salt reactors, but still lower than LWRs (approximately 70 atmospheres). They reach higher reactor temperatures, hence "HTGR,"[52] enabling applications for high-temperature industrial heat or for more efficient electricity generation than LWRs.[53] HTGRs can also be designed to act as fast reactors when a moderator material is not added in the reactor core. Most of these technologies use TRISO fuel, which has HALEU kernels in a fuel pebble. This distinct fuel design is a result of HTGRs' unique fuel assembly, which cannot accommodate the same types of fuel that sodium fast reactors or liquid salt reactors use.

Two SMR-sized models as well as a number of microreactors that use gas coolants are under development. The timelines for commercializing these technologies are uncertain. X-energy plans to construct a four-unit generation facility ready for commercial licensing using its Xe-100 reactor by the "early 2030s."[54] X-energy has preselected Seadrift, TX as the location for their 320-MW plant; however, the plans are still in the preapplication process with the NRC. X-energy and Dow Chemical intend to manufacture the Seadrift HTGR at a Dow facility and assemble it on-site. Also in the preapplication process is the EM2, a 265-MW helium-cooled fast reactor from General Atomics Electromagnetic Systems. Examples of microreactors under development include Ultra Safe Nuclear's Pylon, a 1-MW microreactor, and Radiant's Kaleidos, a 1.2-MW portable microreactor.[55]

3.4 Fusion Reactors

Fusion power plants (Table 1, column 4) use a fundamentally different type of nuclear reaction from all prior and existing nuclear plants, which rely on nuclear fission. Fusion is a nuclear reaction that releases atomic energy by fusing two atoms (typically forms of hydrogen) into a larger, nonradioactive atom such as helium. This process can release large amounts of energy sufficient to make steam for electrical turbines or heat for other uses, though this capability has not yet been successfully demonstrated.

The main technical challenge with fusion is that the fusion reaction occurs when compression and extreme heat turn fuel into fusible plasma. The energy to create this compression can come from magnets, lasers, or other energy sources.[56] Because enormous energy is required to contain and compress fusion fuel to cause the reaction to occur, thus far no commercial company has been able to gain more energy out of a fusion reaction than they put in to cause and contain the reaction.[57] Fusion could become a viable option for New York's energy supply if and when a company can demonstrate both the ability to achieve net positive power generation from fusion and the prospect of doing so at a competitive cost.

Several companies are pursuing commercial fusion and making progress toward the goal of net positive power output. Some of these companies aspire to commercialization timelines that make them relevant for the State to consider as part of its further energy planning. For example, Commonwealth Fusion Systems claims that it will have a commercial power generator operating "within the next decade."[58]

This and other claimed fusion reactor timelines may be unrealistic, but even with a longer commercialization period some consideration of this technology may be warranted. If commercially successful, fusion power has the potential to unlock enormous amounts of carbon-free heat and power ideal for complementing fission, wind, and solar energy. Fusion plants use no uranium-based fuels and therefore eliminate the need for a complex and environmentally difficult fuel supply chain as well as minimize geopolitical and national security issues associated with fission fuels.[59] Although the fusion reaction itself produces high amounts of radiation when operating, the reaction leaves behind relatively short-lived nuclear waste products including tritium that primarily decay to safe levels within decades and do not require long-term storage as do fission wastes.[60] In addition, fusion power plants are considered to be "inherently safe" from plant malfunction accidents because any disruptive incident (loss of power, explosion, etc.) would stop the nuclear reaction and risk only the release of short-lived, low-level radioactive byproducts.[61]

4 Issues for Consideration

Advanced nuclear power generating technologies offer important distinctive advantages and opportunities but also raise a number of significant risks and challenges. The emergent state of advanced nuclear technologies gives rise to the need for discussion of these considerations. Any decision on State action to pursue deployment of nuclear energy in the State requires further inquiry and stakeholder engagement with regard to each issue through the Advanced Nuclear Blueprint Master Plan process that will commence based on this Blueprint.

4.1 Technological and Commercial Readiness

All new energy generation technologies face questions of technical and commercial readiness: does the technology work in commercial applications? As noted by experts at the Oak Ridge National Laboratory, the underlying fundamentals of nuclear technology have been largely unchanged for some time.[62] LWRs have been operated commercially for decades. As for non-LWR approaches, the U.S. has developed, tested, and even operated molten salt reactors, sodium-cooled fast reactors (SFRs), and HTGRs for over five decades, but never on a commercial basis.[63]

In the heavily regulated nuclear industry, the final stages of commercial approval are determined by the NRC. Readiness is also demonstrated by commercial activity, such as advance purchase orders and financial commitments by suppliers and other sources of support. The NRC's determination is very specific to each reactor design, and similarly project development and finance decisions tend to link perceived and acceptable commercial risk levels to a specific technology design, so each new option moves on its own path and timetable. Historically, readiness milestones in nuclear technologies have often been extended due to technical challenges that take longer to resolve than expected. For example, reactors using non–light-water coolants require fabrication of new materials and acceptance of manufacturing processes for them into codes and standards—a process whose timing is difficult to predict.[64]

In the often-lengthy period prior to a new reactor design entering the NRC licensing process, the stage of technological development and timeline to commercialization is especially difficult to assess. Nonetheless, many developers of new advanced nuclear technology options have predicted near-term commercial readiness. Both TerraPower's Natrium reactor and X-energy's Xe-100 reactor projects selected for cost-sharing by the Advanced Reactor Development Program (ARDP) of the U.S. Department of Energy (DOE) claim that they will be online by 2030.[65] The ARDP also provided five additional U.S.-based reactor development teams with grants to address technical and regulatory issues on designs that they claim could have demonstration projects operational by 2035.[66] There is also increased recent commercial activity. Google has ordered several SMRs from Kairos, Amazon has agreed to help develop four SMRs with Energy Northwest, and two data center operators, Equinix and Oracle, have also reached development agreements with SMR vendors.[67] Meta has released a request for proposal (RFP) requesting industry proposals to help it develop 1-4 GW of nuclear generation by the early 2030s, indicating that it is exploring both conventional scale and SMR projects.[68]

In addition to the readiness of the specific reactor, the readiness of the fuel supply for each new reactor type must also be assessed. All advanced LWRs will use LEU, which already has a mature supply chain since it is used in contemporary reactors, or low-enriched uranium plus (LEU+), which does not have a mature supply chain at this time.[69] As noted in section 3, other advanced nuclear technology options other than fusion use one of several new forms of uranium fuel. The facilities that manufacture these fuels, even those currently licensed by the NRC, are not established in commercial operation, and their commercial maturity is just as important as reactor readiness. As an example, the Natrium demonstration plant discussed above has delayed its proposed operating date beyond 2028 due to the lack of its particular fuel, zirconium alloy fuel rods filled with HALEU.[70]

4.2 Licensing, Safety, and Siting

4.2.1 Safety Risks and Perceptions

All nuclear reactors must possess safety systems that, in the event of irregular operating conditions, can control (stop) the fission reaction, ensure the adequate cooling of fuel, and prevent the release of radioactivity into the environment. Statistics indicate that the U.S. commercial nuclear industry's safety record has been strong and improving, with the lowest level of overall safety-related impacts of any major energy source.[71] Nonetheless, public concern about nuclear safety remains high, prodded by the highly visible accidents at Three Mile Island (1979), Chernobyl (1986), and Fukushima (2011).

Advanced reactors offer the promise of safer designs that could reduce both the likelihood and consequences of core damage events.[72] All of the advanced technologies take advantage of passive safety features that cause a reactor to shut down safely without the need for operators to take remedial action after the loss of electrical power or reactor coolant. These systems instead rely on the laws of physics to function; the AP1000, for example, has a passive safety system which uses natural air convection and gravity to relieve pressure and lower the reactor's temperature if coolant is lost or the main steam line breaks.[73] SMRs and other advanced LWRs achieve the necessary safety functions through passive systems and their geometric designs.

Advanced reactors also integrate safety features that are derived from the basic material and chemical characteristics of the design, many of which are in use today in active reactors.[74] This is referred to as "inherent" safety, which describes features of the design of a reactor or its fuel that allow the reactor to safely function and shut down during a loss or failure of coolant. For example, all reactor designs built in the U.S. are legally required to have a negative reactivity coefficient, also called the "void coefficient" or "fuel temperature coefficient," a design feature which means that the number of nuclear reactions occurring in the reactor will decrease as the reactor's temperature increases.[75] In the event of a loss of coolant, this makes a "runaway" reaction theoretically impossible and allows the reactor to shut down safely. This does not preclude reactors from "melting down" after shutdown due to "decay heat," or the heat released from the radioactive decay of fuel left in the reactor; however, some fuels used in advanced reactors possess inherent safety features that make meltdowns extremely unlikely.[76] The design to automatically power down safely may not eliminate all operating or accident safety risks. The reactor design must perform as it has been designed to act, including the behavior of many new processes, reactions, parts, and materials that will be new in the advanced technologies. The NRC's current licensing process for all new, advanced nuclear reactors has so far utilized only historical data and may not account for all of the projected environmental conditions resulting from climate change.[77] However, a new report from the Government Accountability Office has established a framework for the NRC to more comprehensively integrate climate change considerations in its licensing process.[78]

While advanced reactor designs do inherently reduce the risk of a meltdown, as with all reactors, their performance could depend on operating conditions. To cite two examples: (1) the success of a sodium-cooled fast reactor's ability to prevent a runaway reaction relies on the temperature of the coolant remaining stable during a core disruptive accident, which is not guaranteed;[79] and (2) for HTGRs, many of the inherent safety features rely on the quality of the TRISO fuel and could potentially be undermined by any defects in the facility that produces the fuel.[80]

Concerns have also been expressed about the NRC's ability to regulate and ensure safety for the large number of very different reactor designs that are likely to enter full-scale licensing in the next several years. These concerns have been expressed by both nuclear opponents, who are concerned that the agency is rushing approvals in response to criticisms that it has been too slow, and nuclear proponents, who believe the NRC is not moving fast enough and does not have sufficient staffing and expertise.[81] The recently-enacted federal ADVANCE Act aims to address some of these issues by directing increases in the NRC's staff, among other measures. It is also worth noting that there is now explicit international collaboration between U.S., Canadian, and UK nuclear regulators to share licensing-related information and best practices, which should speed and improve advanced reactor licensing.[82]

4.2.2 Physical and Cyber Security

In addition to perceived safety risks from the reactor facility designs, ensuring physical security and nonproliferation of nuclear materials related to advanced technologies are concerns that are the responsibility of the NRC and other national entities. There are two distinct physical security threats, known as "design basis threats" (DBTs) that the NRC considers when evaluating the safety of a reactor facility: radiological sabotage (e.g., terrorists attacks), and theft or diversion of nuclear materials.[83] The current NRC framework is based on LWRs; however, SMRs and non-LWRs could require different or additional physical security requirements,[84] which the NRC is considering in an ongoing rulemaking process.[85]

While not unique to nuclear generation, cybersecurity of nuclear control systems and related assets is a further relevant consideration given the attendant safety risks.

4.2.3 Siting Challenges and Opportunities

Advanced nuclear technologies possess characteristics that have the potential to serve as grid connected facilities or industrial co-location facilities. Ideally, with the inherent safety design features, advanced designs may allow for units to utilize existing power infrastructure and provide local communities with economic opportunities.

In evaluating applications for reactor sites, the NRC has a predefined list of siting criteria that address reactor design/power, engineering standards used, probability of accidental release of radiation, passive and inherent safety features, meteorological, geological, and hydrological conditions at the site, and population density.[86] Specifically, the NRC requires reactor sites to be at least 20 miles away from population centers (defined as areas with 500 or more people per square mile).[87] In 2023, the NRC proposed guidance to expand potentially available sites for advanced nuclear plants by relying on technology-inclusive, radiation exposure risk-informed, and performance-based metrics when determining siting of advanced reactors, including both light-water SMR and non-LWR technologies.[88]

Moreover, thermal pollution from plants co-located with natural water sources has also been associated with measurable negative environmental impacts.[89] This can be mitigated through comprehensive environmental studies prior to siting to better understand the marine environment's response to a potential plant that are used to formulate and adopt mitigation strategies. Potential mitigation strategies include cooling towers, though they can add significant cost. As mentioned above, this will not be a concern for some advanced reactor types which do not require location near a body of water.

There may be additional capacity to host further reactors at New York's existing nuclear sites.[90] This could offer significant advantages in terms of existing infrastructure (such as grid access), shared facilities, and local community support. Other considerations relevant to site selection include location requirements that any co-located off-taker might have as well as NRC licensing requirements.

Consistent and deliberate engagement with communities in areas for potential new nuclear facilities is an essential component of sound energy planning and environmental justice. Siting conversations must engage all community stakeholders early, with the opportunity to state and address concerns, to ensure that any opportunity provided by any new energy resource is fully deliberated.

4.3 Environmental and Climate Justice

New York is committed to integrating environmental and climate justice considerations into the actions needed to address the transition to a clean energy economy. The Climate Act directs the State to "prioritize the safety and health of disadvantaged communities" (DACs) and requires a minimum of 35% with a goal of 40% of the overall benefits of clean energy and energy efficiency programs, projects, or investments in the transition to be directed to these communities.[91]

The environmental and climate justice dimensions of advanced nuclear options begin with the mining and processing of uranium fuels. The most common method of mining uranium today is through "In-Situ Recovery (or Leaching)," a process in which liquid is injected into the ground to dissolve the uranium and then extracted later.[92] This limits the exposure of both miners and surrounding ecosystems to damage from mining activities and any contamination from the uranium when compared with older methods.[93] Notably, water quality protection considerations associated with uranium mining in the U.S. are more stringent than other countries, where mines often operate in locations where local water quality is already compromised and therefore unusable.[94] In the U.S., uranium mining occurs predominantly on land that is owned, governed, and inhabited by Indian and Tribal Nations, frequently disrupting sacred sites and raising strong equity concerns.[95]

If new nuclear plants of any size are sited in New York, environmental and climate justice issues will be extremely important to assess and prioritize for the communities surrounding the plant.[96]

4.4 Cost, Financing, and Policy Support

Nuclear plants in the U.S. have a long history of substantial cost overruns. The most recent commercial reactors to be completed, the Vogtle units, were originally estimated to cost $13 billion ($5,834/kW) but eventually cost $32 billion ($14,362/kW), with a seven-year delay.[97] An analysis of the cost overruns identified some best practices that were not followed, especially emphasizing preproject planning and project management. Other factors mentioned in the analysis were the bankruptcy of Vogtle's initial EPC contractor due to the fixed-price nature of its contract and increased accrual of interest during construction as delays mounted.[98] In addition, suppliers "lacked experience…to successfully manufacture nuclear components," leading to high rates of manufacturing failure. Finally, reductions in the price of natural gas created supplier commitment risk, as investors and suppliers worried about Vogtle's ability to price its electricity output competitively and thus demanded more assurances.[99] Notably, South Carolina's proposed VC Summer plant (which also used Westinghouse AP1000 Gen III+ reactors), was cancelled under the weight of cost overruns in the billions.[100] Concerns of cost overruns have also affected newer technologies such as SMRs. For instance, Utah Associated Municipal Power Systems (UMAPS) recently withdrew from a deal with NuScale to construct six SMRs after overnight capital costs nearly quadrupled from an initial estimate of approximately $5,000/kW to over $20,000/kW.[101]

For any new nuclear reactor technology, a FOAK plant's cost will be high and very uncertain. Costs will be high because details underlying the design, construction, and manufacturing remain exploratory and immature, leading to longer construction periods, less efficient execution, costly specialized parts, and more rework. The uncertainties may be even higher than those associated with offshore wind, which sought to replicate already-mature technologies and construction methods from Europe. Costs and cost uncertainties will tend to decrease with learning and supply chain development when progressing toward a NOAK plant. Consideration should also be given to the opportunity to unlock further cost reductions through multiunit orders and deployment at brownfield sites.[102]

Several studies estimate the costs of FOAK and NOAK plants, as well as "between-of-a-kind" (BOAK) between FOAK and NOAK, which might be relevant for New York if building on the designs of the FOAK projects identified in Table 1. Table 2 below summarizes overnight capital cost estimates from a recent meta-analysis by Idaho National Laboratory for non–technology-specific advanced nuclear technology.[103]

Table 2. Estimated BOAK Overnight Capital Costs for Large Reactors and for SMRs (2022 USD)

Source: Recreated from p. vi, Idaho National Laboratory, Meta-Analysis of Advanced Nuclear Reactor Cost Estimations, July 2024

Advanced Reactor Type	Estimated Costs
Large Reactor (1,000 MW)	\$5,250 - \$7,750 / kW
SMR (300 MW)	\$5,500 - \$10,000 / kW

NOAK project costs should be lower but are also uncertain and will take more time to be revealed. For example, DOE's liftoff report projects a \$4,700/kW NOAK overnight capital cost for AP1000s, down from around \$15,000/kW (\$11,000/kW nominal) for Vogtle units 3 and 4.[104] The liftoff report also estimates that at least 5 to 10 reactors of one standard design need to be built to realize NOAK costs.[105] SMR Start, an industry group, estimated Light Water SMR NOAK costs to be \$2,500/kW with a 10% learning curve and \$2,000/kW for a 15% learning curve, assuming NOAK costs are reached after 36 units.[106]

Given the varied state of technology across the current suite of advanced nuclear technologies, it should be acknowledged that the timing for development of any of these technologies will depend on the time for plant designs and construction capabilities to progress on a learning curve, the development of associated supply chains, and the successful demonstration of facilities to satisfy safety, performance, and scalability considerations. New York has the opportunity to participate in the national activities that are designed to lead to technology demonstrations and supply chain development, which may involve the cultivation of local labor forces and supply chain niches. Even where demonstration projects are potentially uniquely designed, or given construction processes are partly technology specific, consideration of participation in demonstration projects that cultivate labor and supply chain development may be beneficial.

Development concepts for a FOAK plant would have to consider how best to allocate construction cost overrun and cancellation risk among customers, plant developers, plant construction firms, capital providers to all these parties, the State, and the federal Government. There are a number of potential contractual and financial structures present themselves for consideration, as well as opportunities in current or upcoming federal government technology support programs.

Further federal assistance would be essential for pursuing a FOAK plant, recognizing the public-good value of the learnings that would enable others to build plants further down the cost curve. Federal assistance could include a federal cost guarantee, loan guarantee, or direct federal assistance in aid of construction. In addition, new plants could take advantage of tax credits made available by the Inflation Reduction Act:[107]

- The Clean Energy Investment Tax Credit (ITC) can credit developers 30% of a plant's initial capital cost if meeting wage and apprenticeship requirements, with additional bonuses of 10% each for use of domestic content and location within energy communities.
- The Clean Energy Production Tax Credit (PTC) offers developers credits of up to 2.75 cents per kWh assuming satisfaction of wage and apprenticeship requirements, with similar bonus categories to the ITC, except with a 3-cent per kWh addition per criteria met.

Nontaxable entities such as state and local governments or rural electric cooperatives can elect to receive the value of the tax credits as a direct payment from the Internal Revenue Service (IRS). Developers of microreactors could also seek assistance from a variety of federal customers. For example, the Department of Defense's Project Pele recently awarded contracts to two microreactor developers.[108]

As part of overall consideration of advanced nuclear within the larger state energy policy and planning context, it is also appropriate to consider whether and how state financing and financial support mechanisms might be deployed for these technologies. Options include public-private partnerships, modification of state policies and markets for credits for nonemitting generation, and other policies. Other means of support could come from combining in-State advanced nuclear developments with other states' developments, creating scale economies in initial orders.

4.5 Supply Chain and Workforce

4.5.1 Plant Construction Supply Chain

Any nuclear plant (or fleet of smaller ones) requires specialized and non-specialized labor all converging in one place to work with several major types of specialized equipment, components, and materials. The interrelated nature of complex nuclear construction means delays or quality problems in one element affect the others and prolong work crew timing and costs, with the potential to create cascading project delays. With more regulation of components as well as a smaller margin of error than other types of large infrastructure projects, nuclear plants' exposure to these risks is high, and the effects of delays can compound.

One often-cited challenge for plant builders is a weak U.S. nuclear construction supply chain following a several-decade pause in building new plants.[109] Few domestic manufacturers are "N-stamped" by the American Society of Mechanical Engineers (ASME) to provide nuclear-grade components, though not all advanced nuclear technologies require this type of certification on their equipment. The NRC has also deemed items with a commercial-grade dedication as equivalent to an item designed and manufactured under a 10 CFR Part 50, Appendix B quality assurance program. Until domestic suppliers obtain this certification, which takes considerable commitment and time, some advanced options will remain reliant on foreign suppliers for many critical components and compete with overseas plants under construction for limited supplies. At the same time, the possibility of creating a domestic nuclear supply chain could represent a significant economic development opportunity for New York, building on the State's existing suppliers of nuclear technology and services. Opportunities for the State to determine if State-level policies can influence supply chain improvements and how shortages and the maturity of different supply chains may impact economic development should be explored.

A fairly well-established global supply chain exists for at least the Gen III+ LWR equipment, components, and materials to support the development of early projects, albeit with uncertainties and risks for certain components that are novel or poorly specified by the plant designer. In addition, many developers of new technologies are acutely aware of supply chain issues and have been participating in developing new suppliers for their designs, although more project commitments are needed to solidify the development path. The DOE's Nuclear Supply Chain Deep Dive report offers an extensive look at the new types of factories needed to sustain an advanced nuclear technology component supply chain and the certifications required for both new plants and existing manufacturers. Supply chain is also an area in which international collaboration and experience will be important. To cite one example in the fuel supply chain, the U.S. leads a group of five nations who have jointly agreed to invest more than $4 billion in the nuclear fuel supply chain.[110]

4.5.2 Construction and Operating Labor Supply Chain

One uniquely important part of the construction supply chain is construction labor. According to Reuters, large-scale nuclear plant builds require about 1,200 workers,[111] many with specialized trades such as nuclear-certified welders, pipefitters, HVAC technicians and electricians.[112] At peak construction, there were over 9,000 workers on site during the construction of Vogtle units 3 and 4.[113] The DOE Advanced Nuclear Liftoff report projects that about 275,000 workers will be needed for construction and manufacturing if advanced nuclear plant construction reaches the levels it believes are necessary for achieving nationwide net zero by 2050, or 200 GW of new nuclear.[114] Approximately 100,000 additional workers will be needed to operate the new reactors, working in long-term positions.

A particular emphasis on developing craft labor is essential, especially as national craft labor shortages continue to impact the construction industry. In 2023, 88% of craft labor construction firms reported having difficulty filling open positions.[115] This raises concerns over the availability of both skilled and unskilled labor for plant construction, but also an opportunity to create many new high-paying construction jobs in the State. Training of an expanded workforce will require partnerships with local organizations, including universities and technical colleges. The State can potentially alleviate construction and operating labor supply issues by developing apprenticeship and preapprenticeship programs to develop the local workforce and instituting craft labor contracting policies to attract and maintain employees.

4.5.3 Fuel Supply Chain Development

Fuel production involves a several-step process, from mining uranium ore and refining it into U_3O_8 “yellowcake powder,” to converting U_30_8 into UF_6 gas, to enriching to higher concentration of the radioactive U-235 isotope, to processing into UO_2 and fabricating fuel rods or pellets.[116]

New water-cooled reactors use the same LEU fuel that is used in current reactors and can draw on the same mature supply chain. Although the U.S. has some uranium reserves and used to have processing capability, it has almost entirely been relying on more cost competitive supplies from Canada, Australia, Russia, Kazakhstan, and Uzbekistan.[117] If the U.S. increases its reliance on nuclear energy, energy security concerns may require re-onshoring part of the fuel supply chain and expanding non-Russian uranium supplies. This is highlighted by Russia's recent temporary restrictions on enriched uranium exports to the U.S. in response to sanctions imposed by the U.S. in May 2024.[118]

Nearly all of the non–water-cooled reactors will need new supply chains to produce HALEU fuels. Currently the world's only commercial HALEU production comes from the Russian company Tenex. As mentioned previously, the supply of HALEU is a bottleneck for advanced nuclear reactors coming online and proving their technological readiness. A new U.S. fuel supplier, Centrus Energy, delivered its first 100 kilograms of HALEU to the DOE in late 2023, as part of the DOE's plan to acquire 290 metric tones (MT) of HALEU needed to establish domestic demand.[119] Centrus used funds from the $700 million released by the Inflation Reduction Act to "help establish a reliable domestic supply of fuels for advanced reactors using HALEU."[120] Additionally, Orano and the State of Tennessee recently announced the selection of Oak Ridge, TN, as the preferred site for construction of a new uranium enrichment facility that will be designed to produce LEU and HALEU.[121] While commercialization of HALEU production is still being developed, the DOE has been using "downblending" of high-enriched uranium (HEU) stockpiles to produce HALEU, but the surplus stockpiles of HEU may only produce 15 MT of HALEU.[122]

4.6 Fusion Reactors

Fusion power generators raise questions and issues that are quite distinct from many of the considerations affecting fission-based plants. Fusion plants use various forms of hydrogen or helium as fuel, where hydrogen is widely available from many domestic as well as international sources.[123] The absence of uranium fuel removes the need for uranium mining and milling, which have environmental considerations, as well as fuel enrichment and fabrication, which imply radiation safety, proliferation, and further environmental and waste considerations. In addition, as mentioned in chapter 3, fusion plants are inherently safe, with no possibility of heavy radiation-release accidents, and create no long-lived radioactive wastes. Together these attributes have led the NRC to use a comparatively modest and rapid permitting process for fusion plants, with an approximate single-permit timeline of about 2 years.

While these advantages may make fusion an attractive option, all forms of fusion are still in early demonstration. No fusion researcher or aspiring reactor manufacturer has created a sustainable fusion reaction that lasts more than a few milliseconds nor creates multiples of the energy used by the process. Demonstrating sustained technical feasibility is therefore the first critical issue for further consideration of fusion as a resource for the State.

After technical feasibility is established, the second critical threshold fusion power must clear is economic. There is too little information available today to determine the cost of building or operating a commercial fusion power plant and the resulting competitiveness of such a plant against other options. Accordingly, while it is fully appropriate for New York to closely monitor technical developments in fusion power, there is simply not enough information to give it full consideration as a potential supply option in the State's near-term energy roadmaps.

4.7 Research and Development

There is still a considerable need for further research on a wide variety of nuclear power technology aspects to help progress the industry. NYSERDA has an opportunity to play an important role in this research, leveraging the State's extensive, high-quality energy research ecosystem. Topic areas for advanced nuclear research that have been identified thus far that could benefit from New York research resources include but are not limited to:

- Research and development (R&D) on new ways of extracting uranium, in particular from seawater.
- R&D relating to the materials in high temperature reactors, including compatibility with industrial processes and other high temperature applications.
- R&D on steam turbine efficiency: current nuclear steam turbines are only performing at 30% efficiency. Further studies into steam turbine efficiency could help to significantly increase the output of nuclear power plants.

4.8 Waste Generation and Disposal

Waste generated by nuclear fission remains radioactive for many years after it is produced, with some elements remaining radioactive for thousands of years. Although the volume of this waste is not large— all the spent fuel generated by U.S. commercial reactors since 1950 could fit on a 100-yard football field with a depth of less than 10 yards[124]—proper handling, storage, and disposal of the fuel is critical to ensuring public safety.

Currently, nearly all spent nuclear fuel is managed on-site at the generation facility in the form of solid spent fuel rods stored in deep pools of water for approximately 10 years after generation, and then placed in steel-lined concrete casks on the reactor site. While on-site storage is intended to be temporary (the NRC licenses on-site storage in pools and dry casks for 120 years from the plant's initial startup),[125] there are no available permanent disposal sites in the U.S.,[126] and virtually all nuclear fuel used for electricity generation still sits at the facilities where it was generated.[127] While this approach has been successful in preventing waste leakage, as dry casks approach their maximum licensing period, the risks of their failure increase. The federal government has paid over $7 billion to nuclear utilities and reactor owners in legal settlements for failing to take possession of their fuel waste and therefore requiring owners to continue to store the spent fuel on-site.[128] The continued storage of spent fuel at reactor sites also represents a safety risk, as these are potential targets for terrorist or hostile nation attacks.

The NRC has issued a Generic Environmental Impact Statement (GEIS) for public comment, and this GEIS includes analysis of those environmental impacts that may be addressed generically, as well as those that must be addressed on a site-specific basis through supplemental environmental reviews. New York has submitted comments to this GEIS, including comments on waste storage.[129]

Advanced nuclear reactors produce some similar types of waste to their conventional counterparts, but the specific reactor design may produce waste streams that differ in both composition and physical form from conventional reactors, resulting in potentially different requirements for waste disposal and management for different fuels and reactor technologies. Additionally, many designs incorporate increased fuel efficiency and waste reduction. For instance, fast neutron reactors, discussed above, have the ability to produce or “breed” more fuel than they consume while also reducing some of the waste contained in conventional spent fuel.[130] Recycling waste fuel is also being researched, recognizing that spent fuel has only used a fraction of the potential energy available for nuclear fission.[131]

Ultimately, the responsibility for building a spent fuel storage and disposal plan for advanced nuclear technologies rests with the federal government. Spent fuel storage is regulated nationwide by the NRC; should a national repository become a reality, the federal government will be responsible for its management. There are some notable efforts by the private sector to offer expertise in spent fuel storage, such as Deep Isolation, which recently received a grant from the U.S. Department of State to assist several foreign governments in their development of SMR-specific waste management strategies.[132]

5 Master Plan for Responsible Advanced Nuclear Development

5.1 Master Plan Studies

As a next step to consider the future of advanced nuclear power in New York, NYSERDA, together with the Department of Public Service, will embark on a process to draw up New York's Master Plan for Responsible Advanced Nuclear Development. This process will include development of a range of studies to assess issues identified in this Blueprint and offer recommendations. Subject to further scoping activities as discussed below, the range of studies is expected to include:

- **Technical Feasibility and Applications**

  Assessment of nuclear technology and design options: technical and commercial readiness of various reactor technologies and designs under development; specific consideration of range of applications and use cases to support economic development and industry electrification.

- **Regulatory, Safety and Siting**

  An assessment of regulatory pathways and timelines including an inventory of the federal, state and local licensing and permitting regime, including safety and siting aspects; identification of the roles of New York State agencies and authorities in regulating and enabling advanced nuclear projects in New York state.

- **Environmental and Climate Justice**

  Examination of the direct and indirect benefits and challenges of siting new nuclear facilities within DACs, either as new power generation or as associated with conversion of former fossil fuel generation sites; evaluation of methods of meaningful engagement with local and underserved communities, and Indian and Tribal Nations.

- **Policy Options**

  Assessment of nuclear technology and design choices and business models across the range of Gen III+ and Gen IV options identified in this Blueprint; consideration of the related support policy options to facilitate and enable advanced nuclear deployment; and quantification of the estimated associated cost.

- **Supply Chain, Workforce, and Economic Development**

  Consideration both of New York's needs for a supply chain and workforce that would enable in-State advanced nuclear construction, operation and fuel supply, as well as the economic opportunities for New York companies to participate in the domestic and global supply chain markets.

- **Fusion**

  Assessment of the state of progress on nuclear fusion and opportunities for New York to advance this technology (e.g. through one or more demonstration projects).

- **Research and Development**

  An assessment of the technological challenges and opportunities relating to advanced nuclear generation and the priorities and roles New York and federal agencies could pursue in advanced nuclear R&D to improve outcomes and lower costs.

- **Waste**

  Assessment of nuclear waste management processes and options to ensure safe, efficient and cost-effective storage and disposal of nuclear waste generated by new advanced nuclear generation (in particular as regards Gen IV).

Assessment of the issues specific to advanced nuclear in the Master Plan process will need to take place within a context of broader resource planning and strategic considerations. Resource planning examines many possible combinations of supply and demand resources, along with storage, delivery, and end-use technologies, to find cost-effective portfolios that meet state and utility objectives, including maintaining sufficient dispatchable resources to meet grid needs. Accordingly, the Master Plan process will be conducted within the context of a number of other relevant proceedings, in particular the State Energy Plan process,[133] the Public Service Commission proceeding relating to achievement of New York's goal of a zero-emissions grid by 2040,[134] and other resource planning processes led by the NYISO.

5.2 Master Plan Timeline and Stakeholder Engagement

Publication of this Blueprint was preceded by a public comment period on an earlier draft of the Blueprint published in September 2024. Comments received were incorporated into this Blueprint as appropriate to reflect the Blueprint's nature as a scoping document for the Master Plan process.

In addition, a wide range of comments were received that pertain to the Master Plan process itself, namely comments offering views and expertise on how some of the issues raised in the Blueprint should be addressed, and more generally whether and how action on advanced nuclear in New York should proceed. This feedback will help to shape the work of the Master Plan process ahead. Building on the comments received to date and the Master Plan studies, the Master Plan process itself will be designed to incorporate input from those holding specific topical expertise and to solicit and consider stakeholder and constituency input on how the State could or should proceed.

As a first step following the publication of this Blueprint, NYSERDA will form several technical working groups in the spring 2025, made up of topical experts, key constituencies, State agencies and others who can offer important expertise and/or input. Initial working group meetings will be used to further define the scope of the studies, assess the interaction and overlaps between studies and determine the best ways of engaging throughout each study period. Subsequent meetings will inform the Master Plan development process by supporting the development and review of study drafts through multiple forms of engagement, including expert presentations and round table discussions. As the Master Plan studies progress, NYSERDA will, as appropriate, offer draft reports to technical working groups to solicit further input as the studies are finalized. The Master Plan development process is expected to conclude with publication by the end of 2026.

Many of the issues raised in this Blueprint are of keen interest to New Yorkers, and the Master Plan process will identify opportunities to provide updates and solicit feedback throughout. Further specifics on the above process and opportunities for stakeholder involvement will be posted on NYSERDA's Advanced Nuclear web page; for questions in this regard, NYSERDA can be contacted at the following email address: nuclearmasterplan@nyserda.ny.gov.

Endnotes

[1] New York State Senate, 2019. *S6599–Climate Leadership and Community Protection Act*, 2019, 17, lines 34–47, https://legislation.nysenate.gov/pdf/bills/2019/S6599

[2] State of New York Department of Public Service, 2024. "Department of Public Service Staff Proposed Definitions of Key Terms in PSL §66-p," Case 15-E-0302, November 4, 2024.

[3] New York State Climate Action Council, 2021. "New York State Climate Action Council Scoping Plan," Appendix G: Integration Analysis Technical Supplement New York State Climate Action Council Scoping Plan, December 2021, Climate.ny.gov/ScopingPlan, 50. See also NYISO, 2023–2042 System Resource Outlook (July 23, 2024) ("Today, the grid largely relies on fossil generators to provide the aforementioned reliability attributes. To achieve a zero- emissions grid, a collection of generation technologies, referred to as DEFRs, must be developed and deployed throughout the State to provide, in the aggregate, sufficient grid services to maintain reliable electric service for all New Yorkers. The importance of DEFRs continues to be a critical factor as identified in the prior Outlook. In the Outlook, DEFRs are added to the postulated future resource mix to supply essential characteristics, such as dispatchability and flexibility capabilities to support a high renewable system…. The results in this Outlook, however, show an increased reliance on [DEFRs] to provide both peak capacity and hourly energy to support a highly renewable system. This increased reliance is driven by the forecasted hourly profile of demand and the limitations on the duration of energy storage resources.").

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[13] David Solan et al., 2010. "Economic and Employment Impacts of Small Modular Nuclear Reactors," Energy Policy Institute, June 2010.

[14] US Energy Jobs, 2021. "Wages, Benefits, and Change Supplement to the Annual U.S. Energy and Employment Report,*"* 2021, 58. Individuals working in utilities in the nuclear industry receive the highest median hourly wage at $47/hr (25% above the average utility worker in the U.S.).

[15] Nuclear Energy Institute, 2021. "Nuclear in the Neighborhood," December 2021, https://www.nei.org/news/2021/nuclear-in-the-neighborhood

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[23] D. Bass et al., 2022. "Steam Electrolysis Hydrogen Production with Nuclear Reactor Temperature Capability," 2022.

[24] For the purposes of this report, "MW" (megawatt) and "kW" (kilowatt) will be used to represent "MWe" (Megawatt electric) and "kWe" (kilowatt electric), the electrical power output capacity of a plant. This is distinct from a reactor's capacity in MWt (megawatt thermal), which is the thermal capacity of the reactor required to drive the turbine that produces the plant's electrical output.

[25] The 115th U.S. Congress Public Law 115–439 (2019) distinguishes the difference of "advanced nuclear reactors" from commercial reactors in operation today by significant improvements in inherent safety features, significantly lower levelized cost of electricity, lower waste yields, greater fuel utilization, enhanced reliability, increased proliferation resistance, increased thermal efficiency, or the ability to integrate into electric and nonelectric applications. The U.S. Department of Energy's Pathways to Commercial Liftoff: Advanced Nuclear report considers Gen III+ (large light water and light water SMRs) and Gen IV reactors as "advanced" reactors, see DOE at 16. Alternatively, the U.S. Nuclear Regulatory Commission designates advanced nuclear reactors as non-light water reactors, see NRC, Advanced Reactors (non-LWR designs).

[26] NRC, 2021. "Moderator," March 2021, https://www.nrc.gov/reading-rm/basic-ref/glossary/moderator.html. The NRC defines a moderator as, "A material, such as ordinary water, heavy water, or graphite, that is used in a reactor to slow down high-velocity neutrons, thus increasing the likelihood of fission."

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[30] Gen IV International Forum, "Generation IV Goals, Technologies and GIF R&D Roadmap, https://www.gen-4.org/generation-iv-criteria-and-technologies.There are currently six reactor types that the Gen IV International Forum classifies as Gen IV: very-high temperature reactors (VHTR), sodium-cooled fast reactors (SFR), supercritical-water-cooled reactors (SWCR), gas-cooled fast reactors (GFR), lead-cooled fast reactors (LFR), and molten salt reactors (MSR).

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17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

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