Implications of Inflation Reduction Act Tax Credits for Advanced Nuclear Energy

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Disclaimer:
The views expressed herein are solely those of the authors and the Nuclear Innovation Alliance.

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Abbreviations

CCUS........Carbon Capture, Utilization and Storage

DOE…..Department of Energy

EIA……Energy Information Administration

FFB……Federal Financing Bank

FOAK…First of a Kind

IOU…….Investor Owned Utility

IPP……..Independent Power Producer

IRA……Inflation Reduction Act

ITC…….Investment Tax Credit

LCOE….Levelized cost of electricity

LPO…...Loan Program Office

MW……Megawatt

MWh…..Megawatt-hour

NGCC… Natural gas combined cycle

NIA……Nuclear Innovation Alliance

NOAK...N^{th} of a Kind

O&M......Operation and Maintenance

PPI……..Producer Price Index

PTC……Production Tax Credit

w/…..with

w/o…..without

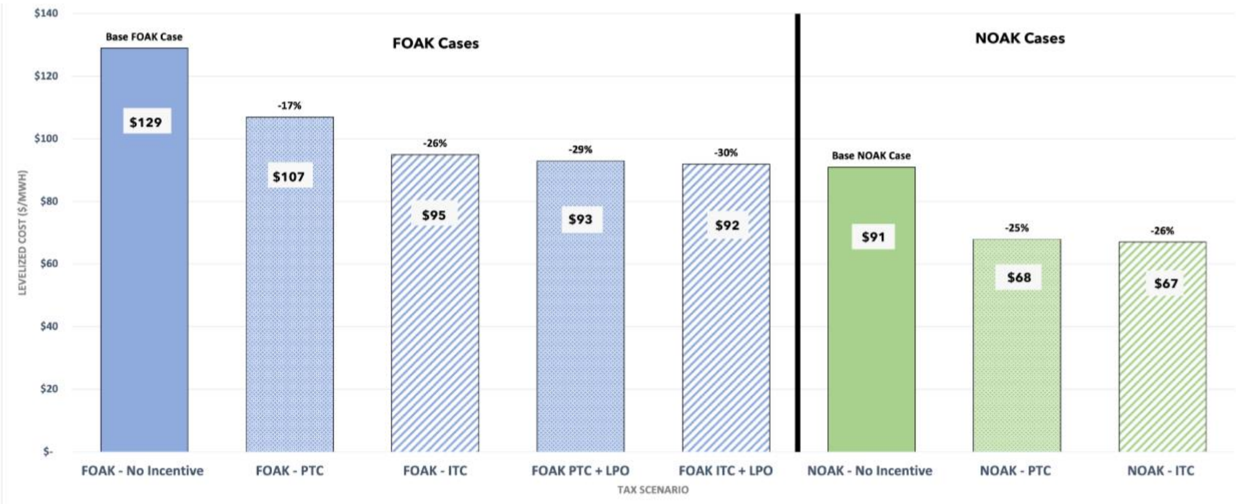
Executive Summary

In 2021, the Nuclear Innovation Alliance (NIA) and NIA consultant Jeffrey Brown conducted an initial tax policy analysis to analyze what financial tools advanced nuclear energy would need to compete in evolving energy markets across the United States. Based on that initial analysis, NIA recommended the adoption of larger and more accessible tax incentives for nuclear energy, specifically for new nuclear projects. Several of these improvements were included in the Inflation Reduction Act (IRA) that was enacted in August 2022.

This paper focuses on the impact of these tax credits on new nuclear projects, using the same tools developed for the initial 2021 analysis to examine how the IRA tax credits will affect the costs and competitiveness of advanced nuclear energy systems going forward. We examined the impact of a project owner utilizing either of two options for tax credits offered under the IRA: a production tax credit (PTC) that is paid for each MWh of energy produced for the first 10 years of the project or an investment tax credit (ITC) that defrays a portion of the original construction cost. We assumed that project developers would be eligible for enhanced tax credits based on fulfilling the IRA's prevailing wage and apprenticeship requirements and siting the project in an "energy community." We applied this analytical framework to estimates of the cost of financing, construction and operating "first-of-a- kind" (FOAK) advanced nuclear projects as well as cost estimates for subsequent "n^{th} of a kind" (NOAK) projects that are less costly to build as a result of learning effects over time, using ranges of construction cost to capture uncertainties. For FOAK projects, we also looked at cases where a project would also qualify for favorable loan terms offered by the Department of Energy Loan Program Office (LPO).

Figure ES-1 displays the impact of the IRA (and LPO) implementation on the overall cost of generation from advanced nuclear projects, under the mid-point case of assumed construction costs. Both the Production Tax Credit (PTC) and Investment Tax Credit (ITC) options that developers can utilize (either one but not both) are shown. Implementation impacts range from a 17 percent reduction (PTC applied to FOAK project) to a 30 percent reduction (ITC with LPO support of FOAK project). The results of this analysis show that the current IRA tax credits effectively reduce the costs of electricity produced by advanced nuclear projects, both for FOAK and NOAK projects. These IRA tax credits enable advanced nuclear reactors to compete directly and effectively with other clean, dispatchable generation options that qualify for similar IRA tax credits, according to a recent DOE report. Therefore, IRA tax incentives will ensure that advanced nuclear technologies will play a significant and expanding role in reducing fossil fuel use and emissions from electricity generation.

Executive Summary Figure 1: Summary of PTC and ITC effects on New Nuclear Cost



Note: Estimates of IRA impacts assuming the midpoint of capital cost estimates for advanced nuclear generation units.

Section 1: The Inflation Reduction Act

Market and Policy Context

Achieving an affordable, reliable and low-emitting energy system requires substantial investment in clean energy infrastructure, including deploying both existing clean energy technologies as well as rapidly developing new innovative technologies and approaches.

This energy transition already is underway in the United States, but policies are needed to accelerate the process to achieve climate and energy security goals and to ensure that benefits and burdens are allocated equitably. Developing and deploying innovative technologies requires public policies that support research and development and stimulate private investment in emerging technologies. Examples of policies that leverage private investment include tax credits and loan assistance programs to defray the cost of deploying existing technologies and reduce the risks of investing in newer technologies. This is the approach adopted by the Inflation Reduction Act (IRA) of 2022, signed into law on August 16, 2022.

Inflation Reduction Act: Approach and Design

Many clean energy technologies are currently in various stages of commercial development, and more will undoubtably appear. Not all will ultimately find a market, but to accelerate deployment and to enhance prospects for commercial success, the IRA makes tax credits available to clean generation options on a "technology neutral" basis. In the electricity generation sector, these tax credits apply in a uniform manner to the construction or operation of various clean generation technologies such as nuclear and renewables, as well as to storage technologies. By defining the magnitude of tax credits identically across a range of different clean generating options, the technology-neutral approach to tax credits is designed to incentivize the deployment of clean energy more efficiently and cost-effectively without *a priori* picking specific winners or losers in the market.

Although the tax credits apply uniformly across clean energy technologies, the amount of the tax credit granted to any specific project depends on certain aspects of the project's development that affect the scale of benefits that arise from the tax credits. The circumstances that qualify for enhanced tax credits are:

- Paying prevailing wages for construction labor and for engaging in apprenticeship programs that develop workforce skills;
- Locating projects in "energy communities" that have experienced economic distress from the clean energy transition, such as the retirement of a coal-fired powerplant; and
- Meeting domestic content requirements for the equipment installed, so that the benefit from the investment is broadly shared in the U.S. economy.

Beyond the tax credits, other provisions of the IRA provide support for clean energy investment. For example, the IRA includes incentives and other support for clean hydrogen production, clean energy manufacturing, critical materials mining, and other supply chain enhancements to nurture a domestic clean energy industry. In addition, there are other policies such as funding for the Loan Program Office (LPO) at the U.S. Department of Energy to provide loan guarantees to lower the financing costs of emerging technologies.[1]

[1] For more information about DOE-LPO authority and how the Inflation Reduction Act affected LPO, please see https://www.energy.gov/lpo/inflation-reduction-act-2022

IRA Advanced Nuclear Energy Tax Provisions

The IRA created two new technology-neutral tax credits for zero-emitting clean electricity projects: a Clean Electricity Production Tax Credit (PTC) and a Clean Electricity Investment Tax Credit (ITC).[2] The clean electricity tax credits are designed to accelerate deployment of clean energy technologies, including advanced nuclear reactors. A project developer can elect either tax credit—but not both—and the value of the credit depends on satisfying other criteria such as paying prevailing wages, incorporating domestic content, and siting the facility in a community that has experienced the recent retirement of traditional generation facilities. Below is a summary of the two new tax credits from which advanced nuclear energy projects can choose:

Table 1: Technology-Neutral Tax Credits included in the Inflation Reduction Act[3]

Tax Provision	Value without satisfying wages and apprenticeship requirement	Value with satisfying wages and apprenticeship requirement	Additional Bonuses
Clean Electricity Production Tax Credit (PTC)	0.5 cents/kWh	2.5 cents/kWh	10% bonus if project is located within an energy community
			10% domestic content bonus
Clean Electricity Investment Tax Credit (ITC)*	6% of initial capital cost	30% of initial capital cost	10 percentage points if project is located within an energy community
			10 percentage points domestic content bonus

*The Clean Electricity Production Tax Credit adjusts for inflation every year; the values in this table are given in 2021 dollars

The IRA strongly encourages clean energy project developers to invest in workers and communities by requiring project developers to pay prevailing wages and provide apprenticeships in order to gain a five-fold increase in the value of the PTC or ITC from their most basic levels (increasing from $5 to $25 per megawatt hour (MWh) for the PTC and from 6% to 30% of capital cost for the ITC). The IRA grants additional "bonus" tax credits for projects that are sited in "energy communities" (areas that experience adverse impacts from energy market transitions), and/or use materials or install equipment made primarily in the United States. Federal tax-exempt entities such as municipally owned power utilities and not-for-profit cooperatives are eligible for "direct pay," which means they can receive a payment from the government in lieu of a tax credit. For tax-paying private entities, the tax credits are transferable to any other taxpayer who may be in a better position to fully utilize the tax credit.[4] The values of both credits

[2] It should be noted that the Qualifying Advanced Energy Project Credit (48C) program was established by the American Recovery and Reinvestment Act of 2009 and expanded with a $10 billion investment under the Inflation Reduction Act of 2022. This paper does not perform an analysis of 48C but at the time of publication, the U.S. Department of the Treasury and the Internal Revenue Service, in partnership with DOE, have announced up to $4 billion in a first round of tax credits for projects that expand clean energy manufacturing and recycling; critical materials refining, processing and recycling; and for projects that reduce greenhouse gas emissions at industrial facilities.

[3] For the latest information on guidance for bonus content, see the Internal Revenue Service website at https://www.irs.gov/inflation-reduction-act-of-2022

[4] This mechanism allows an entity whose tax liability is less than the value of the tax credits to transfer the credits to an entity with sufficient tax payment to fully utilize the credits. This transaction would involve the recipient paying the transferer for the use of the credit, where the payment is typically slightly less than the nominal value of the credit.

over time increase with inflation, but the mechanism is different for the PTC and ITC. The PTC is explicitly escalated by the increase in a general price index, in this case the Consumer Price Index-Urban (CPI-U) computed by the Bureau of Labor Statistics, while the dollar value of the ITC – defined as a percentage of eligible capital costs – will rise as capital costs increase (which may occur at a different rate than general price inflation).

To be eligible for either credit, projects must be placed in service after December 31, 2024, and the PTC would be available only for electricity produced during a facility's first ten years of operation. The credits begin to phase out for new facilities that commence construction after 2032, or when power sector greenhouse gas emissions decline by 75% relative to 2022 levels, whichever is later. When that criterion is met, both credits would phase out over a three-year period: 75% of the initial value after the first year, 50% of the initial value after the second year, and 0% after the third year.

Section 2: Quantitative Analysis of IRA Impact on Advanced Nuclear Energy

Although the IRA tax credits reflect a technology-neutral approach to supporting clean energy technologies, when applied they will affect the costs and competitiveness of clean technologies differently depending on the technologies' underlying cost and performance characteristics. Such characteristics include the relative size of capital and operating costs and the expected amount of annual generation from the technology, factors that also influence the developer's choice of taking the ITC or PTC (along with other market and risk considerations). Significant challenges to assessing the impact of tax credits on costs and competitiveness include uncertainty regarding the current and future costs of advanced nuclear energy plants as well as recent price inflation (and interest rate hikes) that affect all energy technologies.

Advanced Nuclear Construction and Operating Costs

Analysis of capital costs of advanced technologies typically focuses on two cost categories: "first-of-a-kind" (FOAK) and "nth-of-kind" (NOAK) capital costs. The former involves estimating the capital costs associated with building the first commercial power plant of a certain technology type. The latter involves estimating the cost of a power plant after several (three, five or more) similar power plants have been placed into service. A NOAK power plant costs less to build than a FOAK plant, as it benefits from the cost-saving lessons learned in the earlier deployments of that technology type.[5]

The costs of constructing advanced nuclear power plants are uncertain. Despite a growing pipeline of pre-commercial advanced nuclear demonstration and pilot projects, there are very few recent commercial deployments of advanced nuclear power plants. Nonetheless, several recent studies analyze advanced nuclear costs and prospects for cost reductions over time via learning effects associated with building several similar plants over time.[6] The NIA convened a group of nuclear experts to advise energy system

[5] Another approach is to model cost reductions explicitly, starting with a FOAK cost and assuming parameters to generate lower costs for each subsequent unit until the costs converge to a steady state.
[6] See for example, A. Stein, et al., "Advancing Nuclear Energy," The Breakthrough Institute, July 2022, and U.S. Department of Energy, "Pathways to Commercial Liftoff: Advanced Nuclear," April 2023.

modelers on appropriate advanced nuclear cost and performance parameters. In its report,[7] that group noted that advanced nuclear capital costs are "a very important—perhaps the most important modeling parameter. Several modeler participants indicated that capital cost has a larger impact on advanced nuclear energy deployment than any other input parameter."[8] The report recommended a preliminary range of values for capital and operating costs (expressed in 2020 dollars) that could be used in energy system models while the DOE and/or national laboratories conduct a thorough evaluation of cost and performance parameter estimates.

We adopt the recommended cost values from the NIA modeling report in this analysis, inflating those values by about 2% to bring the costs to mid-2021 price levels, the point in time when price inflation in construction-related activity began to rise more sharply than general price inflation.[9] The ranges for FOAK and NOAK construction costs in dollars per kilowatt ($/kW) are shown in Table 2.

Table 2: Capital Cost Parameters Used for Analysis

Technology Maturity	Overnight Capital Costs by Scenario (mid-2021 $/kW)
First of a Kind (FOAK)	High – 7,700
	Mid – 5,700
	Low – 3,700
Nth of a Kind (NOAK)	High – 5,100
	Mid- 3,600
	Low – 2,100

We do not attempt to capture the most recent cost changes for several reasons. First, while recent price indices for construction (buildings and equipment) have increased much faster than overall price inflation, those indices do not necessarily reflect accurate cost increases for specific types of construction, such as building nuclear power facilities. Second, most of the existing literature on alternatives to nuclear power plants, such renewables with energy storage, report costs that reflect 2020-2021 prices, and thus the impact of recent construction cost inflation on the levelized costs of those non-nuclear technologies is not yet available. Finally, some of the commodities that have experienced rapid price increases have fallen from recent highs, and such price deflation may help to reduce construction costs over the next few years, when new nuclear plants might commence construction.

The capital cost ranges in Table 2 above capture the inherent uncertainty in developing newer technologies. While operation & maintenance (O&M) and fuel expenditure estimates vary as well, the variation of those costs is lower. Table 3 below reports the O&M and fuel expenditure values that we use in this analysis.

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[7] See more at: https://nuclearinnovationalliance.org/modeling-advanced-nuclear-energy-technologies-gaps-and-opportunities

[8] J. Greenwald, et al., "Modeling Advanced Nuclear Energy Technologies: Gaps and Opportunities," The Nuclear Innovation Alliance, January 2023, page 3.

[9] For illustration of the significant increase in construction costs, the Producer Price Index for New Industrial Buildings (PCU236211) rose about 32 percent between July 2021 and December 2022, compared to the general price inflation (CPI-U) of about 9 percent over that period. See more at: https://fred.stlouisfed.org/series/PCU236211236211

Table 3: O&M Cost Parameters Used for Analysis

Operating Cost	Advanced Reactors
Fixed O&M ($/kW-year)	4.5% of Construction Cost
Variable O&M and Fuel ($/MWh)	$25

Modeling the IRA for Investor-Owned Utilities

In order to examine the impact of IRA tax credits on the costs of advanced nuclear generation, we used a model developed by NIA consultant Jeffrey Brown that represents the financial flows (including taxes) for a nuclear project over a 30-year period. The model computes a long-run “break-even” price ($/MWh) for generation where revenues from wholesale energy markets exactly balance after-tax costs of financing the construction and operation of the plant. This approach enables an analysis of the effects of tax credits or other financial policies on the overall average cost of producing power, a metric sometimes called the levelized cost of electricity (LCOE).[10]

The inputs for the financial cost model in this analysis include:

- Cost of constructing and operating advanced nuclear generation facilities;
- The expected performance of nuclear generation, *i.e.*, the annual capacity factor[11] (assumed at 90 percent);
- The capital structure of the owner or project, *i.e.*, the proportions of debt and equity;
- The interest rate on debt and the target rate of return on equity; and
- The corporate profit tax rate and allowed depreciation schedule.

In this section, we examine investor-owned utilities (IOUs).[12] For purpose of this analysis, we assume they can use the IRA tax credits to offset current tax liability without having to transfer the credits to other entities with greater tax liabilities. In this case the owner benefits from the full value of the tax credits. Future analysis could include applying these tax credits to public utilities that could take advantage of the Direct Pay[13] mechanism available under the IRA.

We examine the impact of the PTC and ITC in the case where advanced nuclear projects would qualify for two enhancements from the base tax credit levels, which we believe represents a likely scenario. The first such enhancement would arise from paying prevailing wages in construction and offering qualified apprenticeship programs. Meeting this requirement is extremely likely since the increase in the value of the tax credit (an additional 24% of construction cost for the ITC and an additional $25/MWh in the PTC)

[10] While useful for comparing the impact of policies on generation technologies with similar operational characteristics, LCOE models generally are not suitable for assessing the relative value of disparate technologies as they might operate differently in changing electricity markets. Our analysis focuses on the impacts of tax credits on the LCOE of a single representative advanced nuclear generating plant under a range of assumed construction costs.

[11] Capacity factor is a measure of the average utilization rate of an energy generation asset, such as a power plant, wind farm, or solar installation. For example, if a wind farm has a total installed capacity of 100 MW and generates 262,800 MWh per year (an average of 30 MW during each hour), its capacity factor would be 30%.

[12] In the case of a rate-regulated IOU, our computed LCOE can also be viewed as a “revenue requirement per MWh” - the plant-level cost basis used to set retail rates.

[13] Tax-exempt and governmental entities will, for the first time, be able to receive a payment equal to the full value of tax credits for building qualifying clean energy projects. See more at https://www.whitehouse.gov/cleanenergy/directpay/

is almost certainly greater than any plausible savings gained by paying lower-than prevailing wages or forgoing apprenticeship programs. Moreover, large construction projects typically employ union labor and pay local prevailing wages, and such projects are routinely promoted for their local economic development benefits.

The second likely tax credit boost would arise from choosing a site for the project in an "energy community," such as an area that recently experienced the retirement of a large coal plant. Even without tax credit incentives, such locations are potentially economically attractive for advanced nuclear project developers because of the potential to reuse some of the assets at the sites of former coal plants, the value of which may already be greater than the associated tax credit bonus. A recent study from DOE suggests that "Coal to Nuclear" (C2N) repowering could reduce nuclear capital costs by 17-35% if a new nuclear project could take advantage of existing land, structures, transmission facilities, cooling water access, etc., and that new nuclear projects would find greater acceptance in such communities. The DOE examined 157 such sites across the United States, at which 70,400 MW of coal capacity had retired during the past decade.[14] The DOE assessment found that many of these sites have the potential advantages for cost-effective site reuse with nuclear energy, compared with development at "greenfield" sites. In addition, the Energy Information Administration (EIA) reports that over 50,000 MW of additional coal capacity will retire between 2022 and 2029, expanding the opportunities to re-develop retired plant sites.[15]

For those reasons, we choose to model the IRA tax provision assuming that nuclear developers will meet prevailing wages and apprenticeships requirements and could meet the siting requirements for energy communities. We are less certain about the bonus for domestic content, given the current state of supply chains and the costs of domestic construction materials (e.g., iron and steel) compared to imports. We believe that projects might qualify for the domestic content credit bonus, but we do not assume that in this analysis.

Section 3: The Effect of IRA Tax Credits on Advanced Nuclear Cost

Results and Findings

First-of-a Kind (FOAK) Projects:

We consider the impact of IRA tax credits and loan guarantees on the costs of FOAK advanced nuclear projects. As stated previously, FOAK projects are characterized by higher construction costs and fixed O&M expenditures than subsequent NOAK projects. Figure 1 shows the levelized costs of FOAK nuclear projects without incentives and levelized costs under the assumed PTC and ITC cases. Without federal support, the levelized cost of FOAK advanced nuclear projects ranges from $98/MWh in the low-cost case to $161/MWh in the high-cost case, and is $129/MWh in the mid-cost case. As expected, both the PTC and ITC options are effective at reducing the costs of FOAK nuclear projects, although they are not identical in their effectiveness. When construction costs are high, the ITC reduces costs by a greater amount than the PTC, while in cases of lower construction costs the ITC and PTC yield similar outcomes.

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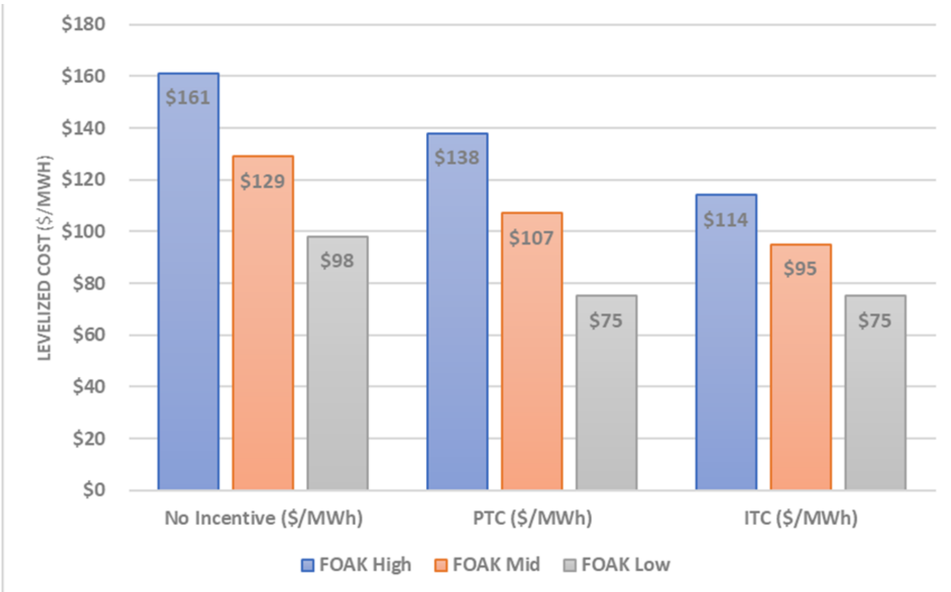
[14] See "Investigating Benefits and Challenges of Converting Retiring Coal Plants into Nuclear Plants," U.S. Department of Energy, September 2022, p. 10. Also see John Jacobs and Lesley Jantarasami, Can Advanced Nuclear Repower Coal Country?, Bipartisan Policy Center, March 2023.

[15] See "Nearly a quarter of the operating U.S. coal-fired fleet scheduled to retire by 2029," Today in Energy, November 7, 2022.

This is intuitive: since the ITC reduces the construction costs by a set percentage, it will yield a greater overall cost reduction for a project with higher capital costs, all else equal.

Figure 1: Levelized costs of FOAK nuclear projects under PTC and ITC cases

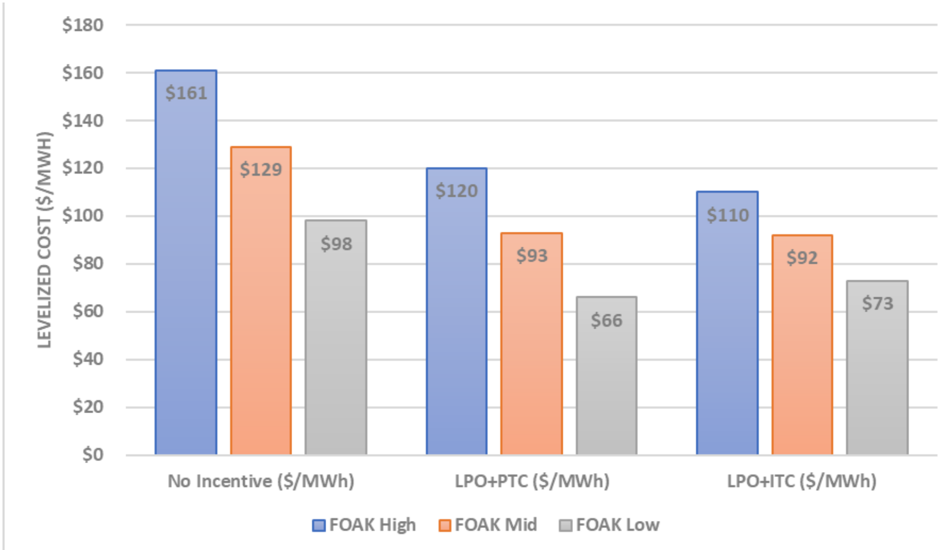


It must be noted that developers will consider a wide range of factors when selecting the PTC or ITC, and small apparent advantages in LCOE are unlikely to drive the decision. Other considerations, such as business and market risks that might affect the value of credits going forward, will play an important role in deciding between the two tax credit types. For example, the PTC involves taking on performance risk for the first ten years of operation, and an extended outage or a change in tax circumstances could significantly diminish the future value of the credit. If construction costs are high compared to the quantity of energy produced the ITC may be more valuable; whereas, in NOAK units with lower construction costs, the opposite could be true. Regulatory treatment of different components of revenue requirements may also influence the choice between ITC and PTC.

Effect of Loan Program Office (LPO) Support on Advanced Nuclear FOAK Costs:

Some FOAK projects may be eligible for loan guarantees provided by the DOE Loan Program Office (LPO), which can be combined with IRA tax credits. The LPO arranges loans to project developers. Those loans are issued by the Federal Financing Bank (FFB) and the terms of those loans are guaranteed by the federal government. The interest rates for such loans are calculated as the applicable rate for US Treasury Bonds with maturity dates identical to the duration of the loan term, plus a FFB "liquidity spread" of 0.375 percent, plus a risk-based charge set by the LPO. We model this as a reduction in the effective debt interest rate from 5 percent to 4 percent, a 20 percent reduction in the cost of debt.

Figure 2: Levelized costs of FOAK nuclear projects with LPO assistance and PTC and ITC



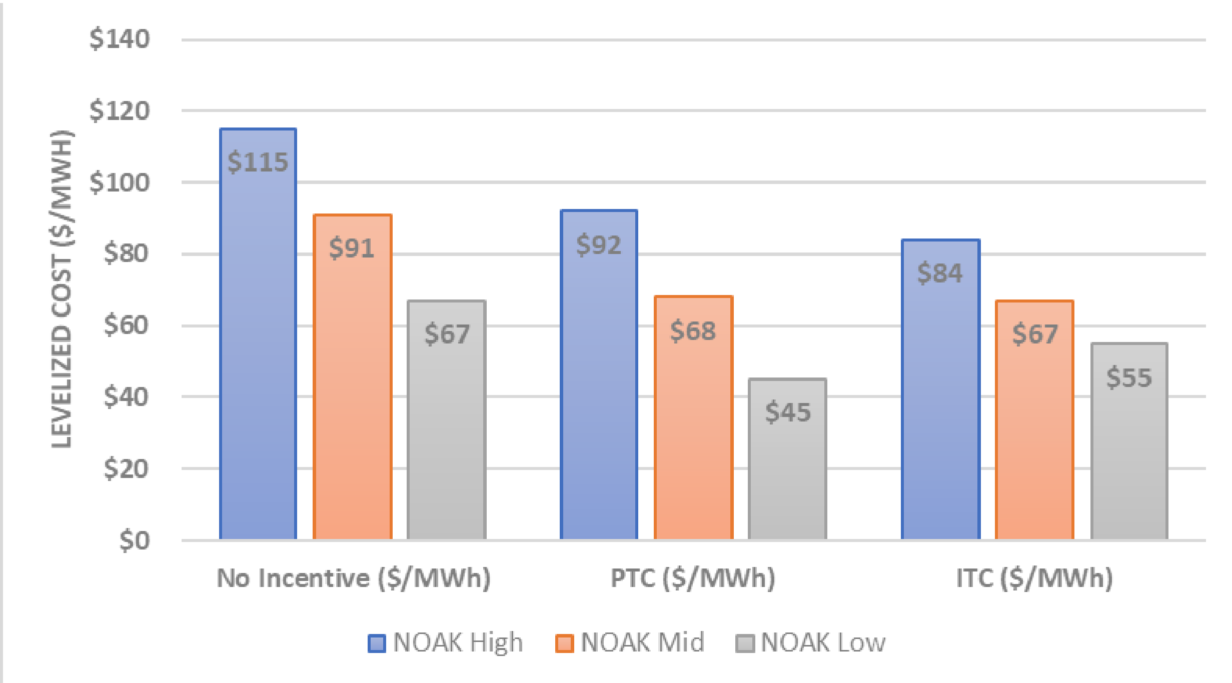
When LPO credit support is combined with the PTC, the result is additive, *i.e.*, the LPO credit support further reduces costs – and revenue requirements from ratepayers – by a substantial amount. This is because the LPO credit support and PTC operate independently: the cash value of the PTC to the utility effectively increases a non-ratepayer source of a revenue during each of the first ten operating years; whereas the LPO debt's below-market interest rate decreases ratepayer-funded expenses each year that capital is recovered through rates. However, this is not the case with respect to LPO credit support and the ITC, which interact during the financing and construction phase. The value of the LPO credit support is eroded under the ITC because the ITC reduces the amount of debt financing required by the project (debt and equity are pro-rated). Therefore, the interest rate reduction from the LPO credit support contributes to a smaller overall cost reduction.[16] In the ITC cases, the combined impact of LPO support and IRA tax credits offset each other significantly.

Nth-of-a-Kind (NOAK) Projects:

Since NOAK nuclear projects, by definition, are neither commercially novel nor unproven, they are not eligible for LPO credit support. As modeled here, the primary difference between FOAK and NOAK projects is the significantly lower construction costs of NOAK projects arising from cumulative project experience. The corresponding NOAK levelized electricity costs, before any tax incentives, are much lower than the levelized electricity costs for FOAK projects. Figure 3 displays NOAK levelized electricity costs that range from $67-115/MWh without IRA tax credits, along with reductions in generation cost due to the application of the PTC and ITC to the NOAK project cost parameters.

[16] This effect may partly be an artifact of the model structure, which holds the debt/equity ratio constant when applying the ITC to the overall capital requirement. An LPO loan recipient might also be able to shift more of the capital structure to (now cheaper) debt, which would amplify the cost reduction from the composite LPO/ITC policy support.

Figure 3: Levelized costs of NOAK nuclear projects using IRA tax credits



Given that NOAK construction costs are lower than FOAK construction costs, the PTC has a larger positive impact on project economics than the ITC, in the case of NOAK projects. Opting for the PTC produces lower costs than the ITC in the low and medium cost cases and the ITC is slightly favored in the high-cost case.

IRA Tax Credits Make Advanced Nuclear Energy More Competitive

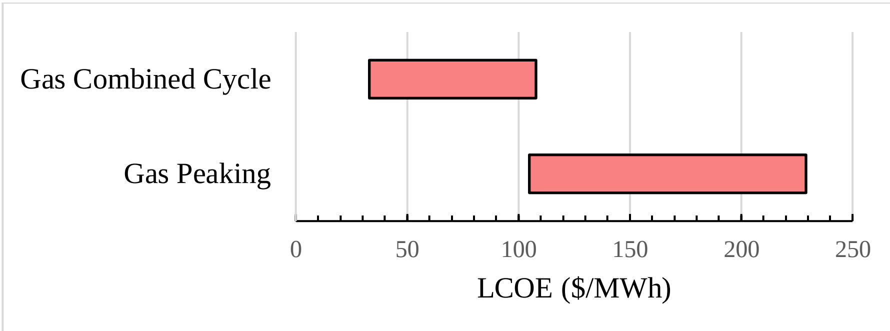
While the IRA tax credits are effective at reducing the cost of advanced nuclear generation, are the cost reductions sufficient to make new nuclear plants a competitive source of clean, firm power? Assessing competitiveness requires meaningful and multi-factor comparisons between technologies with different technical characteristics as they may operate in an evolving, decarbonizing electricity market.

Many argue that LCOE is suited to explore tax policy on electricity generation, however, the LCOE framework used to examine the impact of tax credits does not produce a metric that reliably reflects a technology's competitiveness relative to other technologies. The usefulness of LCOE measures to assess competitiveness breaks down when:

- Technologies provide different products into the electricity market (e.g., energy, capacity, ramping capability, reserves);
- Technologies are expected to operate differently (e.g., starting/stopping, load following, continuous operation) as a function of market conditions and electricity or fuel prices; and/or
- The basic LCOE calculation omits appropriate values for external costs of generation, such as greenhouse gas emissions, that currently are or may be internalized in the future.

For example, natural gas combined cycle (NGCC) is a mature technology that provides dispatchable reliable power, emits greenhouse gases arising from the fuel (methane) and its combustion (CO_2) and is typically used to "firm"[17] variable energy sources. But natural gas fuel price is a substantial cost component in NGCC operation and changes in natural gas fuel price can substantially affect the capacity factor of NGCC – distorting the LCOE measure that assumes a constant capacity factor.[18] Figure 4 below shows the sensitivity of LCOE measures to gas prices and capacity factors for two gas generation technologies (NGCC and simple-cycle natural gas peaking units) derived from a recent analysis by Lazard.[19]

Figure 4: Volatility of NGCC and Gas Peaking Plants LCOE From Fuel Prices Variability



Note that because gas peaking units are less efficient than NGCC plants and typically operate at much lower capacity factors, variations in gas prices have a more pronounced effect on the range of calculated LCOE measures. Because natural gas-fired generating unit operation (and thus calculated LCOE) is sensitive to volatile fuel prices, comparing LCOE of gas and nuclear does not provide an accurate picture of relative competitiveness. Notwithstanding these issues, a recent LCOE figure for NGCC at an assumed 90% capacity factor (identical to the nuclear capacity factor assumed in this analysis) with current fuel and financing costs was reported at $39/MWh.[20] However, this LCOE does not reflect the greenhouse gas emissions from NGCC operation, and therefore does not represent the true cost of NGCC generation in a grid transitioning to zero emissions over time.

To make valid comparisons among the costs of various technologies -- and to assess their relative competitiveness -- it is necessary to confine LCOE comparisons to those technologies that provide identical services to the grid and comparable environmental impact. Nuclear generating units provide continuous, reliable, firm power (that is, both capacity and energy) to the grid with zero emissions. Therefore, to assess the long-run competitiveness of advanced nuclear energy in a reliable, decarbonized grid, comparable LCOE metrics with generation resources with the same operating and emission characteristics as nuclear must be constructed.

In a recent study, DOE compared the cost of advanced nuclear electricity with that of two other sources of firm, clean scalable power that also qualify for clean energy tax credits: NGCC equipped with carbon

[17] In electricity markets, "firming" otherwise intermittent or variable power means providing assurance of physical power generation during specific time periods.
[18] In fact, higher fuel prices that directly raise generating cost also depress capacity factors, further increasing measured LCOE (with an opposite effect for lower fuel prices).
[19] See 2023 Levelized Cost Of Energy+, Lazard, April 2023, "Levelized Cost of Energy Comparison —Sensitivity to Fuel Prices."
[20] See Lazard's 2023 Levelized Cost of Energy+ Version 16.0. The LCOE for an NGCC operating at a 30% capacity factor was $101/MWh, assuming a delivered natural gas price of $3.45 per million British thermal unit (BTU).

capture and storage (CCUS, which would generate sequestration tax credits); and renewables (wind, solar) coupled with long-duration energy storage (both renewable generation and storage are eligible for IRA clean electricity tax credits) – all of which can be considered low-carbon energy technologies that could provide "firm" variable power output. As explained in the *Pathways to Commercial Liftoff: Advanced Nuclear* (the "Liftoff") report:

> System modeling shows that while renewables will play an essential role, decarbonizing the last ~20% of the grid would be very difficult and expensive without firm power. Firm power refers to generation sources that can provide stable energy supply during all seasons and during periods of weeks up to months. With an increasing portion of the grid supported by renewables, the value of grid stability provided by firm power increases.
>
> As a clean, firm power source, nuclear complements variable renewable generation and is expected to be cost competitive with other sources of clean, firm power (e.g., renewables with long duration energy storage, natural gas with carbon capture) as each of these technologies is demonstrated at scale and moves down the cost curve…[21]

The DOE estimated that advanced nuclear costs, including a 30% ITC, range from $66/MWh (NOAK) to $109/MWh (FOAK), figures that are consistent with the LCOE analysis presented in the previous section. The numbers found in the DOE Report serve as a benchmark for the analysis performed in this study and importantly, show that the range of FOAK and NOAK advanced nuclear energy project costs considerably overlaps with the LCOE ranges for the other two clean, firm technologies when all technologies qualify for tax credits.

Figure 5 below shows LCOE ranges for various technologies under different tax assumptions. The uppermost three LCOE ranges are derived from Figure 6 of the DOE "Liftoff" report.[22] These ranges show that advanced nuclear will be competitive with other clean, firm technologies (renewable generation combined with long-duration energy storage and NGCC coupled with carbon capture and storage) when all qualify for IRA tax credits. The next two LCOE ranges are derived from the analysis contained in this NIA report, showing the LCOE results from FOAK and NOAK analysis using mid-point capital cost assumptions. This shows that the NIA analysis produces advanced nuclear LCOE results under the tax credit scenario that are very close to those shown in the DOE Liftoff report, and that tax credits are critical to maintaining the competitiveness of advanced nuclear as an option for clean, firm power. The sixth and lowest range on the graph repeats the Lazard LCOE for NGCC without CCUS or tax credits as shown in Figure 4 above, which provides some additional context for the LCOE results. When natural gas prices are low (and consequently NGCC capacity factors are high), building new clean, firm generation (nuclear, renewable or fossil with carbon capture) is not generally competitive, even when utilizing tax credits. However, when natural gas prices increase, the additional generation cost and the impact on capacity utilization can increase the LCOE of conventional NGCC sufficiently to make new, clean and firm generation competitive when such technologies are supported by IRA tax credits.

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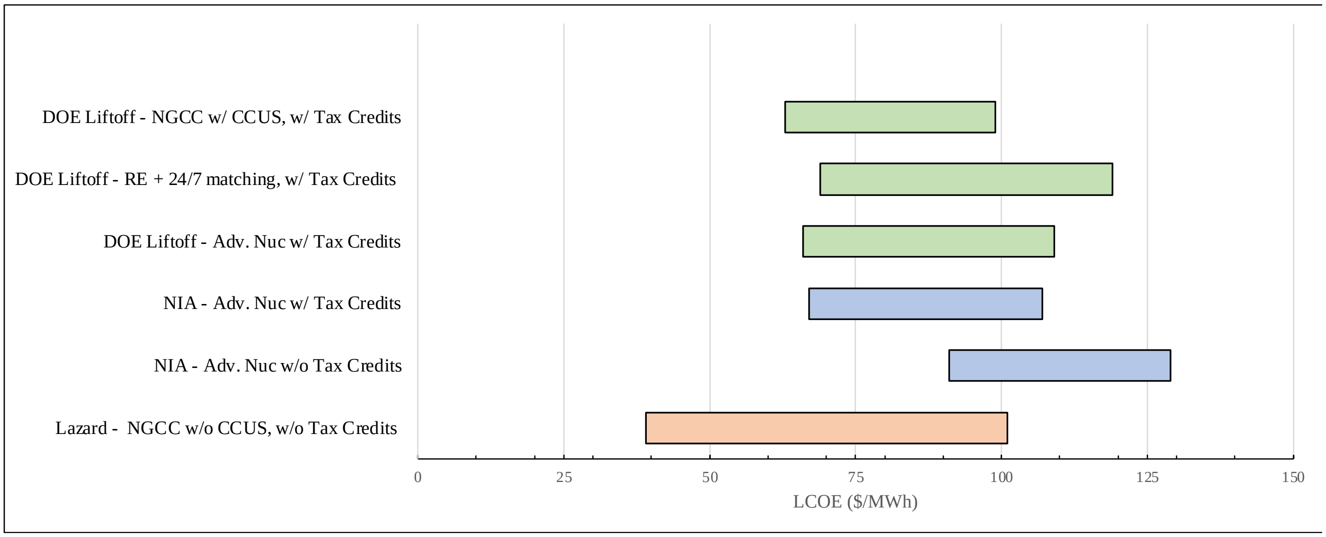
[21] U.S. Department of Energy, "Pathways to Commercial Liftoff: Advanced Nuclear," April 2023, page 9.
[22] U.S. Department of Energy, "Pathways to Commercial Liftoff: Advanced Nuclear," April 2023, page 9.

Figure 5: Advanced Nuclear LCOE with IRA Tax Credits and without IRA Tax Credits Compared to Alternative Clean, Firm Resources and Alternative Carbon-Emitting, Firm Resources



With tax credits, advanced nuclear is competitive in a world that values carbon emission reduction, and without tax credits it could struggle to compete with alternative clean, firm resources that qualify for tax credits. These comparisons indicate that advanced nuclear energy – aided by supportive policy – can play a valuable role in decarbonizing the grid while maintaining reliable, affordable power costs for consumers.