Regulatory Reform & Nuclear Energy

Tyler Linnebur

Final Project – Final Paper

645 – Computational Economics

Dr. Max Brown

December 15, 2025

I. Introduction

Nuclear power has a significant though quite role in long-run decarbonization strategies. It offers a reliable baseload, low-carbon electricity with high capacity-factors and long operating lifetimes, yet new nuclear projects in many countries, particularly the United States, have been characterized by high costs, long construction timelines, and substantial financial risk. Consequently, nuclear power is often judged to be economically uncompetitive based on standard levelized cost of electricity (LCOE) comparisons, even as energy system models continue to rely on it for deep decarbonization and grid reliability.

In reviewing the reactor-level construction and cost literature, I found consistent evidence that construction duration plays a key role in driving nuclear cost outcomes (Koomey & Hultman, 2007; Berthélemy & Escobar-Rangel, 2015; Lovering et al., 2016). Long construction timelines amplify interest during construction, increase exposure to regulatory and design changes, and sharply raise financing costs. At the same time, the literature makes clear that this experience is not universal. In countries with standardized reactor designs, consolidated regulatory authority, and predictable licensing processes, projects tend to be built faster, with more stable schedules and much better cost performance. Taken together, these studies suggest that high nuclear costs reflect not only technological challenges, but also the quality of the regulatory environment in which projects are developed.

Despite this evidence, LCOE-based analyses often treat construction time as a fixed input rather than as a source of uncertainty that investors price ex ante, where downside schedule risk is reflected in required returns even if delays never materialize. In much of the literature, delays enter only as realized outcomes, while discount rates are applied uniformly across projects regardless of regulatory or schedule risk. This modeling choice obscures a central feature of nuclear investment, most financial risk is borne before any electricity is produced, when capital costs are sunk and projects are highly exposed to regulatory hold-up and schedule slippage. As a result, standard cost comparisons tend to understate the economic significance of permitting regimes and overemphasize differences in engineering, operating, or fuel costs.

Ownership structure also matters for nuclear cost outcomes, but its importance depends on the regulatory environment. Publicly owned or regulated projects often benefit from lower costs of capital than privately financed projects, reflecting differences in risk sharing, investment horizons, and access to government-backed financing. At the same time, the literature makes clear that lower discount rates by themselves are often not enough to overcome long and highly uncertain construction timelines. When regulatory delays are severe, they can overwhelm the financing advantages of public ownership. This makes it essential to consider ownership structure and permitting regimes together when interpreting observed nuclear costs or assessing policies intended to revive nuclear investment.

This paper addresses these gaps by explicitly modeling construction duration and schedule risk as financing-relevant variables within an LCOE framework. I use reactor-level construction data to characterize baseline and reformed permitting regimes and then trace how differences in expected build time and uncertainty translate into effective discount rates, IDC, and LCOE. By holding engineering, operating, and fuel assumptions constant across cases, the analysis isolates the institutional and financial channels through which permitting and ownership affect nuclear cost outcomes, rather than attributing cost differences to technology alone.

The central research question of this paper is: how do permitting regimes and ownership structures interact to determine nuclear power costs once construction duration and schedule risk are explicitly priced into financing costs?

The results show that permitting reform plays a primary role in determining nuclear LCOE by sharply reducing both construction duration and schedule risk. These reductions lower effective financing costs and dominate all other cost components. Ownership structure also matters, but its effect depends on the permitting and regulatory environment in which projects are developed. Public ownership delivers the lowest costs only when paired with predictable, low risk permitting environments. Under fragmented baseline permitting, even low public-sector discount rates are overwhelmed by schedule risk. These findings imply that institutional reform, rather than incremental cost reduction or financing tweaks alone, is central to improving the economic performance of new nuclear power.

II. Literature review

The LCOE is the standard framework used to compare electricity generation technologies, translating lifetime capital, operating, fuel, and decommissioning costs into a per-megawatt-hour metric through discounting. For capital-intensive technologies such as nuclear power, LCOE outcomes are dominated by capital costs and the discount rate applied during the construction period. International institutions including the IAEA, OECD-NEA, and IEA implement closely related formulations that separate overnight construction costs from IDC and ongoing operating expenses, reflecting the importance of financing assumptions in nuclear cost assessments (IAEA, 2014; NEA, 2020).

A defining feature of nuclear LCOE models is how they manage construction time. Construction duration affects costs directly through interest during construction and indirectly by delaying revenue. In most standard LCOE frameworks, however, construction time is treated as a fixed input rather than as a source of uncertainty that matters for investment decisions. Discount rates are usually applied after construction outcomes are known, rather than adjusted upfront to reflect uncertainty about how long a project might take. As a result, standard LCOE comparisons implicitly assume that investors face known timelines and that delays, if they occur, are realized surprises rather than risks priced into financing decisions from the start.

This simplification limits the ability of static LCOE models to capture the financial reality of long-lived infrastructure investments. Nuclear power plants operate for 60 to 80 years, yet the bulk of financial risk is concentrated in the pre-operational phase, when capital is sunk and no revenue is generated. Static LCOE frameworks therefore obscure the distinction between expected cost and downside exposure, even though investors are primarily concerned with variance, tail risk, and capital at risk before commercial operation. This gap motivates a modeling approach that treats construction duration not merely as an engineering input, but as a channel through which uncertainty enters investment and financing decisions.

In reviewing empirical studies of nuclear power construction, I find consistent evidence that schedule length is a dominant driver of cost escalation. Early reactor-level work in the United States shows a strong correlation between construction duration and final capital cost, as longer build times increase financing costs and exposure to regulatory and design changes (Koomey & Hultman, 2007). Cross-country analyses reach similar conclusions, indicating that these effects are institutional rather than technological. Berthélemy and Escobar-Rangel (2015) show that longer lead times are associated with higher overnight costs even after controlling reactor size and vintage, pointing to institutional design as a key source of delay.

The most comprehensive empirical assessment is provided by Lovering, Yip, and Nordhaus (2016), who assemble reactor-level cost data for 349 reactors across seven countries. Their results show that cost trajectories vary sharply by country and era, with some national programs exhibiting stable or declining costs over time. Crucially, they reject the notion that nuclear power inherently suffers from unavoidable cost escalation. Instead, they demonstrate that countries with standardized designs, continuous build programs, and coherent regulatory frameworks experienced far less cost growth than fragmented, stop-start programs such as that of the United States.

While construction delays are well established as the dominant driver of nuclear cost outcomes, delay is typically treated as a realized outcome rather than as a risk anticipated by investors. Much of the existing literature is retrospective, focusing on observed construction delays and cost overruns rather than modeling how the risk of delay affects financing terms and investment decisions ex ante (Koomey & Hultman, 2007; Berthélemy & Escobar-Rangel, 2015; Lovering et al., 2016). Consequently, these studies document cost escalation after the fact but stop short of explaining how anticipated schedule uncertainty enters capital pricing before construction begins, despite institutional analyses emphasizing the importance of construction and regulatory risk for nuclear financing (OECD-NEA, 2020). I also found that attempts to explain cross-country differences in cost performance have often emphasized learning-by-doing, with early models predicting cost declines as cumulative experience increased. Evidence from both the United States and France complicates this narrative, leading to claims of negative learning, or “forgetting by doing,” in nuclear construction. Grubler’s (2010) analysis of the French nuclear scale-up is particularly influential, documenting periods of rising costs despite large-scale deployment and attributing these outcomes to increasing system complexity and institutional rigidities rather than to technological immaturity alone.

Theoretical work on irreversible investment provides a framework for understanding how regulatory uncertainty affects capital-intensive projects. Dixit and Pindyck (1994) show that when investments are sunk and future payoffs are uncertain, firms rationally delay investment or demand higher expected returns to compensate for downside risk. Nuclear power exhibits precisely these characteristics: high sunk costs, long lead times, and limited exit options once construction begins. Regulatory uncertainty exacerbates this dynamic through a hold-up problem, as regulators, courts, and intervenors face incentives that favor caution over speed after capital has been committed. Anticipating this asymmetry, investors price regulatory risk into projects ex ante, raising financing costs even if severe interventions never materialize.

The Organization for Economic Co-operation and Development Nuclear Energy Agency (OECD NEA) consistently emphasizes construction risk and political risk as central determinants of the cost of capital in nuclear projects. The NEA highlights that regulatory unpredictability increases perceived idiosyncratic risk, raising financing costs independently of expected construction cost or operating performance. Even when engineering designs and projected operating costs are well understood, uncertainty over licensing, permitting, and judicial intervention leads investors to demand higher required returns. However, I found that much of this institutional literature remains qualitative. While it identifies key risk channels and financing frictions, it rarely embeds these risks formally within cost-minimization or investment models, leaving the link between institutional design and economic outcomes conceptually clear but analytically underdeveloped.

I also found that differences in financing structure play a critical role in mediating the impact of construction risk on project costs. Publicly owned or regulated nuclear projects typically benefit from lower discount rates, longer investment horizons, and explicit risk-sharing mechanisms that reduce exposure to construction delays. In contrast, privately financed projects in liberalized electricity markets face higher costs of capital and shorter payback expectations, making them more sensitive to regulatory and schedule uncertainty. NEA analyses of nuclear financing repeatedly show that the cost of capital is often a larger determinant of LCOE than overnight construction cost itself. Financing mechanisms such as regulated asset base models, construction work-in-progress recovery, and state-backed guarantees reduce the economic cost of risk by reallocating it across broader constituencies rather than concentrating it on private investors.

Related public infrastructure literature argues that applying private-sector discount rates to assets with strong public-good characteristics systematically overstates economic cost (Helm, 2010). Nuclear power's long asset life, intergenerational benefits, and role in system reliability imply that ownership and risk allocation are central determinants of measured cost, not incidental financing choices. In this context, higher private discount rates reflect institutional exposure to regulatory and political risk rather than underlying resource cost.

Despite extensive empirical and institutional analysis, several gaps remain. Construction duration is universally treated as deterministic despite substantial empirical variance. Regulatory delay is discussed descriptively but rarely incorporated into formal objective functions or financing models. Comparisons between public and private ownership are typically qualitative rather than embedded within a unified analytical framework. Finally, the link between institutional design and economic outcomes is often asserted rather than modeled. This paper addresses these gaps by modeling nuclear investment as a cost-minimization problem in which construction duration enters explicitly as a decision-relevant risk channel. Rather than treating delays as exogenous realizations, the model allows regulatory regimes and ownership structures to shape both expected construction timelines and schedule uncertainty, which in turn affect financing costs. The contribution lies not in disputing the empirical record on nuclear costs, but in translating institutional uncertainty into economic outcomes within a formal, policy-relevant modeling framework.

III. Methods

This analysis compares the LCOE for new-build nuclear power plants under alternative ownership structures and permitting regimes, with the objective of isolating how construction duration and schedule risk affect financing costs. All engineering, operating, and fuel assumptions are held constant across cases. Differences in LCOE therefore arise solely from variation in construction timelines and from the pricing of regulatory and schedule uncertainty into the cost of capital. This structure is intentionally parsimonious, allowing the analysis to focus on the institutional and financial channels emphasized in empirical literature rather than on technological or design differences.

The model is indexed over two dimensions. Ownership type, denoted by $o \in \{\text{private,public}\}$ distinguishes between privately financed and publicly financed nuclear plants. Permitting regime, denoted by $r \in \{\text{baseline,reform}\}$, distinguishes between the existing regulatory environment and a reformed regime characterized by shorter and more predictable licensing and construction timelines. These indices define four deterministic institutional cases: private-baseline, private-reform, public-baseline, and public-reform. The model does not attempt to forecast which institutional arrangement will be adopted but instead compares the cost implications of each configuration under the same technical assumptions.

Engineering and operating parameters are fixed across all cases to avoid conflating institutional effects with technological variation. The representative plant is a large light-water reactor with capacity set to approximately 1,000 MW, consistent with average characteristics of the U.S. nuclear fleet. The capacity factor is assumed to be 0.92, reflecting high baseload utilization, and the operating lifetime is set to 60 years. Capital cost, operations and maintenance, and fuel cost inputs are taken directly from OECD-NEA LCOE reference tables and expressed in dollars per megawatt-hour. Because these values are already levelized, they are treated as invariant across ownership types and permitting regimes, ensuring that observed cost differences reflect financing and institutional effects rather than differences in plant design or performance.

Financing and institutional parameters vary by ownership type and permitting regime. The base weighted average cost of capital (WACC) is specified as a function of ownership, capturing differences in financing structure and risk allocation between private and public entities. Private ownership is associated with a higher base WACC, reflecting exposure to construction risk, market risk, and political risk, while public ownership is associated with a lower base WACC due to access to lower-cost capital and broader risk sharing. Construction duration and schedule risk are specified by permitting regime using reactor-level data from the IAEA Power Reactor Information System (PRIS). For each reactor with a reported commercial operation date, construction duration is calculated as the elapsed time between construction start and commercial operation, expressed in years using a 365.25-day year. Cancelled units and reactors still under construction are excluded to ensure comparability across cohorts. For each permitting regime, the mean construction duration and the sample standard deviation of construction duration are computed and interpreted as expected build time and schedule risk, respectively.

Schedule risk is incorporated into financing costs through a reduced-form risk pricing mechanism. The effective discount rate for each ownership-permitting combination is defined as:

$$\boldsymbol{r}_{\text{eff}}(\boldsymbol{o},\boldsymbol{r}) = \textbf{WACC}(\boldsymbol{o}) + \boldsymbol{\kappa} \cdot \boldsymbol{\sigma}_{\boldsymbol{Y}}(\boldsymbol{r})$$

In this formulation, the effective discount rate applied to capital costs is defined as the sum of a base weighted average cost of capital and a risk premium that reflects construction schedule uncertainty. The base term, $WACC(o)$, varies by ownership type and captures systematic differences in financing conditions between private and public entities, such as access to lower-cost capital, risk-sharing arrangements, and investment horizons. The risk premium term, $\kappa \cdot \sigma_Y(r)$, explicitly prices construction schedule uncertainty into financing costs. Here, $\sigma_Y(r)$ measures the dispersion of construction duration under permitting regime r, calculated as the sample standard deviation of time to commercial operation across comparable projects. This dispersion serves as a proxy for uncertainty about when revenue will begin, which is a central concern for investors financing large, irreversible capital projects.

The parameter κ converts each year of schedule uncertainty into an incremental increase in the discount rate and reflects the idea that uncertainty during the pre-revenue construction phase raises required returns even before any delay is realized. Investors must commit capital years in advance, and greater variability in completion times increases the risk that capital remains tied up without revenue for extended periods. The relationship between schedule risk and financing cost is modeled as linear for transparency and tractability. While the true relationship may be nonlinear or project-specific, a linear specification allows the model to isolate the effect of regulatory and institutional uncertainty on financing costs without introducing additional complexity. The value of κ is therefore calibrated rather than estimated, chosen to generate order-of-magnitude changes in effective discount rates consistent with differences observed across nuclear projects operating under different regulatory environments, as discussed in the OECD-NEA financing literature. Importantly, κ is not intended to represent a precise behavioral parameter but to translate observed differences in construction uncertainty into plausible financing outcomes. Even modest values of κ produce large effects on capital costs when construction periods are long, highlighting the sensitivity of capital-intensive investments to both time and discounting.

Construction duration and financing costs are combined through an interest-during-construction (IDC) style adjustment that reflects the time value of capital during the pre-revenue phase of the project. Because nuclear plants require large upfront expenditures and generate no revenue until commercial operation, capital committed during construction accrues financing costs for several years. To capture this effect in a tractable way, capital expenditures are assumed to be incurred at the midpoint of the construction period. This leads to an IDC multiplier defined as:

$$\textbf{idcMult}(\boldsymbol{o},\boldsymbol{r}) = (\boldsymbol{1} + \boldsymbol{r}_{\text{eff}}(\boldsymbol{o},\boldsymbol{r}))^{\textbf{buildY}(r)/2}$$

In this formulation $r_{\text{eff}}(o,r)$ represents the effective discount rate faced by a project with ownership type o under permitting regime r, combining the base cost of capital with a risk premium that reflects construction schedule uncertainty. The exponent $\text{buildY}(r)/2$r represents half of the expected construction duration under the given permitting regime and reflects a midpoint compounding assumption. This assumption captures the idea that capital expenditures are spread over the construction period rather than all incurred at once, so that, on average, funds are committed for half of the total build time before the project begins generating revenue.

The IDC multiplier therefore increases capital costs to account for both how long capital is tied up and how expensive it is to finance. Longer construction periods increase the time over which capital accrues financing costs, while higher effective discount rates raise the cost of carrying that capital. Because these effects interact multiplicatively, projects that combine long construction timelines with high financing costs experience disproportionately large increases in effective capital cost. While this midpoint compounding approach is a simplification relative to a full cash-flow-based IDC calculation, it captures the core economic mechanism linking construction duration, financing conditions, and cost outcomes. By avoiding detailed assumptions about annual spending profiles, the formulation remains transparent while preserving the sensitivity of capital costs to both time and discounting, providing a clear channel through which permitting regimes and schedule risk affect the LCOE.

I computed the LCOE for each ownership-permitting combination as the sum of financing-adjusted capital costs and fixed operating costs. Specifically, I calculated LCOE by multiplying the capital cost component by an interest-during-construction adjustment and then adding operations and maintenance costs and fuel costs, all expressed on a per-megawatt-hour basis, as shown in equation below. This approach follows standard LCOE practice, but I modify the treatment of capital costs to explicitly account for construction duration and financing risk. Because nuclear power is highly capital intensive, changes in financing conditions during the construction phase have a much larger effect on total costs than changes in operating or fuel expenses, making this adjustment central to the analysis.

$$\mathbf{LCOE}(\boldsymbol{o},\boldsymbol{r}) = \mathbf{capCost_{MWh}} \cdot \mathbf{idcMult}(\boldsymbol{o},\boldsymbol{r}) + \mathbf{omCost_{MWh}} + \mathbf{fuelCost_{MWh}}$$

Only the capital cost component is adjusted for construction time and financing risk, while operations and maintenance costs and fuel costs are added as fixed components that do not vary across ownership types or permitting regimes. This reflects the core modeling assumption that permitting reform primarily affects financing conditions and schedule risk rather than reactor technology, operating efficiency, or fuel requirements. By holding non-capital cost components constant, the model isolates the institutional and financial channels through which permitting regimes influence cost outcomes. Any differences in LCOE across cases therefore arise entirely from differences in construction duration, schedule uncertainty, and the resulting cost of capital, rather than from assumptions about technological performance.

To formally identify the minimum-cost institutional configuration, the four LCOE outcomes corresponding to the ownership-permitting combinations are embedded in a simple linear optimization problem. The model minimizes a weighted average of LCOE across cases, where the weights represent the selection of a single institutional configuration. The weights are constrained to sum to one and to be nonnegative, which ensures that the solution corresponds to one feasible case rather than a mixture of outcomes. When combined with the cost-minimization objective, this convex-combination structure forces the optimization to place full weight on the ownership-permitting combination with the lowest LCOE and zero weight on all others.

Importantly, this optimization does not represent investor behavior, diversification strategies, or probabilistic choice under uncertainty. The weights are used purely as a technical device to implement a transparent and replicable selection rule. Instead of manually comparing outcomes across cases, I use the optimization framework to make the selection criterion explicit and to keep comparisons consistent as additional cases or policy scenarios are added. This approach is common in comparative static analysis, where discrete alternatives are evaluated using the same objective without imposing assumptions about behavior. It also provides a clear and flexible foundation for extending the model to more complex institutional or regulatory settings in future work. The model minimizes:

$$\boldsymbol{Z} = \sum_{\boldsymbol{o},\boldsymbol{r}} \mathbf{LCOE}(\boldsymbol{o},\boldsymbol{r})\, \boldsymbol{x}(\boldsymbol{o},\boldsymbol{r})$$

subject to:

$$\sum_{\boldsymbol{o},\boldsymbol{r}} \boldsymbol{x}(\boldsymbol{o},\boldsymbol{r}) = \mathbf{1}, \boldsymbol{x}(\boldsymbol{o},\boldsymbol{r}) \geq \mathbf{0}\ \forall \boldsymbol{o},\boldsymbol{r}$$

The convex-combination constraint requires that the weights assigned to each ownership-permitting combination sum to one and remain nonnegative, which ensures that the solution represents a single feasible configuration rather than a blend of outcomes. Because each weight x(o, r) must be greater than or equal to zero and all weights must all sum to one, the model cannot average across multiple institutional arrangements or construct intermediate cases. Instead, when combined with the cost-minimization objective, this structure forces the optimization to assign full weight to the ownership-permitting combination with the lowest LCOE and zero weight to all others. Importantly, this formulation does not represent investor behavior, diversification, or probabilistic choice. The weights are used solely as a technical device to identify the cost-minimizing institutional configuration in a transparent and replicable way. This approach is consistent with standard comparative static analysis, in which discrete alternatives are evaluated under a common objective without introducing behavioral assumptions, and it provides a clean foundation for extending the model to additional cases or policy scenarios in future work.

IV. Results

The results indicate that permitting reform has a first-order effect on nuclear LCOE by reducing construction duration and, more critically, by sharply reducing schedule risk. Under baseline permitting, long expected construction periods combined with high dispersion in completion times materially increase effective discount rates, producing large interest-during-construction multipliers applied to capital costs. In the model, effective discount rates range from 10.3 percent for publicly owned projects to 15.8 percent for privately owned projects under baseline permitting, reflecting the large schedule-risk premium embedded in financing costs. These elevated discount rates translate into IDC multipliers between 2.1 and 3.0, causing capital costs to dominate total LCOE and explaining much of the variation across cases.

Ownership structure also matters, but its effect is conditional on the permitting environment. Public ownership yields lower LCOE than private ownership due to a lower base cost of capital;

however, this advantage is muted under baseline permitting, where high schedule risk overwhelms financing benefits. For example, under baseline permitting the public ownership case still exhibits an interest-during-construction multiplier exceeding 2.0, resulting in an LCOE of approximately $125 per MWh despite the lower base discount rate. In contrast, under reformed permitting, shorter construction timelines and low schedule risk allow the lower public-sector discount rate to translate directly into reduced financing costs. Effective discount rates fall to approximately 3.0 percent in the public reform case, yielding an IDC multipliers close to 1.1 and lowering capital-related costs.

Public ownership with permitting reform case yields the minimum modeled LCOE, approximately $76 per MWh, which corresponds exactly to the optimal objective value returned by the linear program. On the other extreme, private ownership under baseline permitting produces the highest LCOE, approximately $171 per MWh, driven by the combined effect of a high base discount rate and substantial schedule-risk premia. The spread between these two cases, $95 per MWh, illustrates the magnitude of the institutional and financing channel isolated by the model. In the optimization step, the linear program assigns full weight to the public reform case, with the selection variable equal to one for that configuration and zero for all others, confirming that it is unambiguously cost minimizing within the modeled set of alternatives.

Several limitations of the analysis should be noted. The model is deterministic and compares only four cases rather than modeling stochastic construction outcomes or endogenous investment behavior. Construction risk enters through a reduced-form schedule-risk premium rather than through an explicit probability distribution of delays, and the LCOE formulation applies a simplified interest-during-construction adjustment rather than a full present-value representation of construction-phase cash flows and generation. Engineering, operating, and safety considerations are held fixed by assumption. As a result, the findings should be interpreted as isolating the financing and institutional channels through which permitting regimes and ownership structures affect nuclear costs, rather than as a comprehensive assessment of nuclear project economics.

V. Conclusions

The economic performance of new nuclear power plants is shaped less by technology or operating costs than by institutional design, particularly permitting regimes, and their interaction with financing conditions. Modeling construction duration and schedule risk as determinants of the cost of capital shows that permitting reform has a first-order effect on LCOE, meaning it drives the primary variation in LCOE rather than acting as a marginal adjustment. Long and uncertain construction timelines increase effective discount rates through IDC, dominating all other cost components, while predictable permitting regimes lower financing costs and LCOE.

Ownership structure matters, but only conditionally. Public ownership lowers the base cost of capital, yet this advantage is neutralized under fragmented permitting environments where schedule risk is high. When permitting reform reduces both expected construction time and uncertainty, lower public-sector discount rates translate directly into lower costs, producing the lowest LCOE among the cases considered. The key implication is that ownership alone cannot compensate for institutional sources of delay and uncertainty. Financing reforms without regulatory predictability yield limited benefits, while permitting reform without credible execution leaves much of the potential cost reduction unrealized.

These results help explain why nuclear power has performed so differently across countries and time periods, with high costs in some cases and successful, lower-cost deployment in others. They support the idea that nuclear costs are not fixed by the technology itself, but are shaped by governance, regulatory coherence, and how risk is allocated during construction. When standard LCOE comparisons ignore construction risk, they tend to make nuclear power look inherently expensive, even though much of the observed cost premium reflects institutional failure rather than limits imposed by engineering or resource availability.

Several extensions would improve and deepen the analysis by relaxing simplifying assumptions and expanding the treatment of uncertainty and investment behavior. With additional time and data, the deterministic framework could be extended to a stochastic model in which construction duration is treated explicitly as a random variable with regime-specific distributions. This would allow expected costs, downside exposure, and tail outcomes to be evaluated directly rather than inferred indirectly through point estimates. A stochastic formulation would also permit a clearer distinction between expected construction time and schedule risk, aligning the model more closely with how investors price uncertainty ex ante. In parallel, financing could be modeled using a full present-value framework that tracks cash flows during construction and operation, replacing the reduced-form interest-during-construction adjustment with explicit capital drawdowns, compounding, and revenue timing. Endogenizing investment decisions within this framework would further allow the model to capture option value, strategic delay, and abandonment risk in the presence of regulatory uncertainty, providing a more complete representation of nuclear investment under irreversibility and policy risk.

Additional refinements would address heterogeneity across technologies, institutions, and market environments. Incorporating variation in reactor designs, project scale, learning effects, and supply-chain maturity would allow the model to distinguish between cost differences driven by engineering choices and those driven by institutional execution. Cross-country and intertemporal differences in regulatory structure could be modeled explicitly to assess how changes in governance affect construction risk and financing costs over time. Linking the framework to observed financing instruments, such as regulated asset base models, construction work-in-progress recovery, or state-backed guarantees, would enable a more granular evaluation of specific policy tools and their risk-allocation effects. With sufficient time and resources, the model could be embedded within a broader electricity system framework to examine how institutional reform influences not only project-level costs, but also capacity expansion decisions, system reliability, and decarbonization pathways.

VI. References

Bowen, M., Evans, A., Khan, H., & Ponangi, R. T. (2024). *Reforming nuclear reactor permitting and environmental reviews: Roundtable report*. Columbia University, Center on Global Energy Policy. https://www.energypolicy.columbia.edu

Foster, J., Wagner, L., & Bratanova, A. (2014). *LCOE models: A comparison of the theoretical frameworks and key assumptions (No. 4-2014)*. School of Economics, University of Queensland, Australia.

Grubler, A. (2010). *The costs of the French nuclear scale-up: A case of negative learning by doing*. Energy Policy, 38(9), 5174–5188.

Guaita, N., Spangler, R. M., & Hansen, J. (2025). *Parametric and nonparametric models of U.S. cost overruns for nuclear power plants (INL/CON-25-84516-Revision-0)*. Idaho National Laboratory. https://www.inl.gov

International Atomic Energy Agency. (n.d.). *PRIS Country Details: China*. Power Reactor Information System. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CN

International Atomic Energy Agency. (n.d.). *PRIS Country Details: Republic of Korea*. Power Reactor Information System. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=KR

International Atomic Energy Agency. (n.d.). *PRIS Country Details: United States of America*. Power Reactor Information System. https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US

Jacobs, J., Jantarasami, L., & Fishman, X. (2024, January). *Licensing and permitting reforms to accelerate nuclear energy deployment*. Bipartisan Policy Center.

Lovering, J., Yip, A., & Nordhaus, T. (2016). *Historical construction costs of global nuclear reactors*. Energy Policy.

Lovering, J. R., Nordhaus, T., & Yip, A. (2017). *Apples and oranges: Comparing nuclear construction costs across nations, time periods, and technologies*. Energy Policy, 102, 650–654.

Nuclear Innovation Alliance. (2024). *Key recommendations for reforming U.S. nuclear energy regulation*. Washington, DC: Nuclear Innovation Alliance.

OECD-NEA. (2021). *Unlocking reductions in the construction costs of nuclear: A practical guide for stakeholders (NEA No. 7530)*. OECD Publishing.

OECD-NEA. *(n.d.). Levelised cost of electricity calculator*. https://www.oecd-nea.org/lcoe/

OECD-NEA. (2022). *Financing new nuclear power plants: Minimising the cost of capital by optimising risk management (NEA No. 7632)*. OECD Publishing. https://www.oecd-nea.org

Portugal-Pereira, J., Ferreira, P., Cunha, J., Szkló, A., Schaeffer, R., & Araújo, M. (2018). *Better late than never, but never late is better: Risk assessment of nuclear power construction projects.* Energy Policy, 120, 158–166.

U.S. Energy Information Administration. (n.d.). *How much electricity in the United States is generated from nuclear?* U.S. Department of Energy. https://www.eia.gov/tools/faqs/faq.php?id=228&t=3

U.S. Energy Information Administration. (2022, November 18). *Nuclear explained: Data and statistics. U.S. Department of Energy*. https://www.eia.gov/energyexplained/nuclear/data-and-statistics.php