A Tool to Quantify Capital Cost Reduction Pathways for Advanced Nuclear Reactors

Systems Analysis & Integration Campaign

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A TOOL TO QUANTIFY CAPITAL COST REDUCTION PATHWAYS FOR ADVANCED NUCLEAR REACTORS

This is a brief overview of the 'Nuclear Reactor Capital Cost Reduction Tool' available at this link. A report, 'Quantifying Capital Cost Reduction Pathways for Advanced Nuclear Reactors', has been issued. This report discusses the framework within the spreadsheet tool and provides detailed information on the methodology and assumptions behind the model.

OBJECTIVE

The framework is developed as a tool to showcase different pathways to reducing the capital cost of advanced reactor plants. The intent is to relatively quantify key cost drivers and visualize the evolution of costs as plants are built, not to predict the exact cost of future plants. The Department of Energy Advanced Nuclear Liftoff Report[a] emphasized the importance of driving down capital costs to achieve widespread deployment of nuclear plants to decarbonize the US electricity grid. The report also highlighted the value of utilities and other companies forming large consortia, placing committed order books of nuclear plants, and incorporating the lessons learned from recent nuclear power plant construction projects. The framework described here builds on these key recommendations by attempting to relatively quantify specific pathways toward the cost reduction of advanced nuclear reactors.

MODEL ASSUMPTIONS

The starting point for the framework was two advanced reactor designs referred to as 'Reactor Concept A' and 'Reactor Concept B.' The former is a 4-reactor pack with a large plant output, while the latter is a smaller, single unit plant. These two designs were selected to highlight design-specific considerations and how they impact costs. The model correlates cost and construction duration estimates from the open literature for these two concepts to a set of 'levers' that can be adjusted in the spreadsheet to compute the evolution of costs from the first plant to the last plant in the order book for a given reactor concept. The levers affecting the capital cost are collectively intended to represent the decision-making of stakeholders such as plant owners, investors, and the government. The framework helps visualize the impact of such high-level decision-making on the capital costs of the plants in the order book. The framework is based on several simplifying assumptions regarding scheduling overruns, the number of activities performed at the site versus a factory, the subjectivity of contractor proficiencies, and correlations between various levers. The model performs a deterministic calculation and does not quantify the significant uncertainties involved in nuclear plant construction. All assumptions and underlying relationships are documented in the report.

OVERVIEW OF FRAMEWORK INPUTS

The tool is in the form of an Excel spreadsheet with a sheet named 'Dashboard.' At the top of the sheet, users can select different values for the levers listed and described below:

- **Number of firm orders**: This determines the size of the order book for a given reactor concept. It directly impacts equipment costs for all units within the order (including the first).
- **Include 1st plant in averages**: This lever allows the user to choose to ignore (FALSE) or include (TRUE) the impact of the first plant in the overall order book average (e.g. if investment in the first-of-a-kind [FOAK] is already accounted for separately).
- **ITC Amount**: This represents federal investment tax credits (ITC) that can be claimed by the generation owner after project completion. A value of 40% is considered suitable for the first reactors if they include the bonus credits (e.g., if repurposing a coal plant).

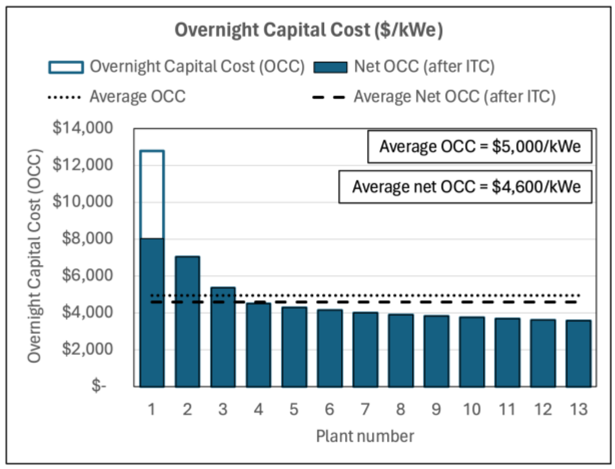
[a] U.S. DOE. 2023. "Pathways to Commercial Liftoff: Advanced Nuclear." https://liftoff.energy.gov/wp-content/uploads/2023/05/20230320-Liftoff-Advanced-Nuclear-vPUB-0329-Update.pdf.

- **Number of Plants Claiming ITC**: This determines how many plants, starting from the first, can claim ITC depending on the speed of construction and assumed expiration timelines for the credits.
- **Interest Rate**: This represents the cost of borrowing money used to finance a project using debt. This is provided as a percentage. This lever may account for any subsidized low-interest rate that a company may qualify for the clean energy investment (e.g., from the DOE Loan Program Office). Also, note that the framework assumes that 100% of the capital investment is debt.
- **Design Completion**: This indicates the percentage of design completed when construction of the plant begins. Historically, FOAK plants have started construction with an incomplete design. When construction begins with a lower design completion, there are typically more licensing amendments and rework, resulting in delays and cost increases. This lever has been identified in the past studies as one of the most significant contributors to cost and schedule overruns.
- **Design Maturity**: This indicate how many NPP designs currently being considered for deployment require new components that have never been built before and potentially result in supply chain delays. This novelty is represented by the design maturity lever. In the framework, this lever can be provided as one of three options: most components are new and therefore design maturity is low (value of 0), most components are deployed in the non-nuclear industry but never in nuclear and therefore design maturity is medium (value of 1), or most components have already been deployed in nuclear and therefore design maturity is high (value of 2).
- **Supply Chain Proficiency**: This represents the proficiency of the supply chain. Proficiency could be interpreted as a combination of a contractor past experience and performance, as well as the methods or technologies used by the contractor to accomplish the tasks. A score between 0-2 (with decimal increments; 0 representing lowest proficiency and 2 representing highest) can be assigned for this lever by the user. Note that this study does not intend to judge the proficiency of these contractors and only intends to highlight the impact of this parameter on cost and schedule.
- **A/E Proficiency**: This represents the proficiency of the architect/engineering (A/E) contractor. Similarly to above, a score between 0-2 (including decimal increments) can be assigned for this lever by the user.
- **Construction Proficiency**: This represents the proficiency of the construction contractor. Again, a score between 0-2 (including decimal increments) can be assigned for this lever by the user.
- **Number of plants to achieve best proficiency**: For each of the supply chain, A/E, and construction proficiency, the maximum proficiency can be assumed to be reached after a certain number of units are deployed. A default value of 3, 4, and 5 units, respectively, is assigned that can be adjusted by the user.
- **Cross-Site Standardization**: This represents the percentage of the design that is standardized between different sites. Typically, elements of the plant design (especially civil works, which constitute account 21 – Structures and Improvements) change due to site-dependent parameters such as topography and local natural hazards (earthquake, tsunami, etc.). Reducing these changes through technologies like seismic isolation will increase standardization between different sites.
- **Modular Civil Construction**: A 'TRUE/FALSE' toggle to represent if the construction leveraged modular methods such as steel composite (SC) walls.
- **Commercial BOP**: This lever determines if the balance-of-plant (BOP) can be commercially sourced from non-nuclear vendors (TRUE) or if it is safety-related and subject to nuclear qualifications (FALSE).
- **Non-Safety Related RB**: This lever represents the safety-related classification of the reactor building (RB). While the RB is typically safety related, advanced reactor technologies with superior passive safety features (e.g., TRISO-fueled reactors) can potentially make the case for not needing the RB for safety function.

OUTPUT OVERVIEWS

For a given selection of levers, the tool computes the construction duration, Overnight Capital Cost (OCC), and Total Capital Investment (TCI) for each of the units in the order book. A series of plots are then generated to visualize the impact of cost reductions from the first to the last plant in the order book. The plots also show the impact of ITC on capital investment, the cost contribution of various accounts (direct, indirect, financing, etc.), and a waterfall chart showing the relative contribution of various levers and variables in the cost reduction. Figure 1 shows the inputs and several of the outputs for a sample scenario. The levers are shown on the left and sample outputs – OCC and the waterfall chart – are shown on the right. The tool also computes the expected timeline for constructing all of the plants in the order book sequentially, assuming a 75% overlap between each subsequent unit. Under the selected levers in Figure 1, constructing the first five units requires 15 years for Reactor Concept A. Note that this does not account for any plants that could be constructed in parallel (but likely may not benefit from experiences gained from concurrent units).

Number of Firm Orders	13
Interest Rate	6%
Design Completion	80%
Design Maturity (0, 1, 2)	1
Supplychain Proficiency (0 - 2)	0.5
A/E Proficiency (0 - 2)	0.5
Construction Proficiency (0 - 2)	1
Cross Site Standard-ization	80%
Modular Civil Construction	TRUE
Commercial BOP	TRUE
Non-Safety-Related RB	FALSE
ITC Amount	40%
Numbers of units with ITC	1



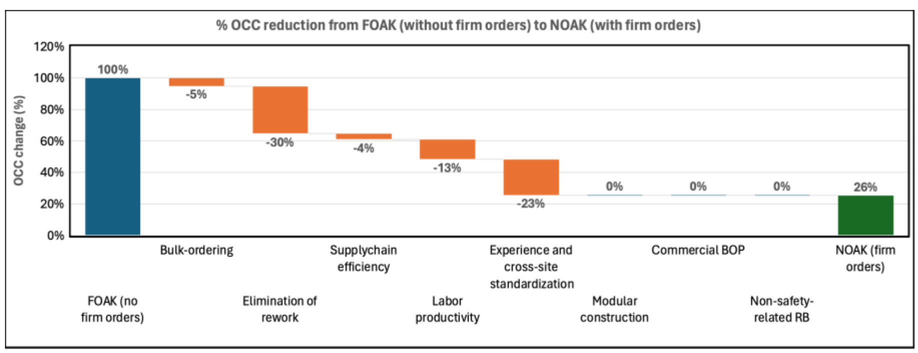


Figure 1. Illustrative example using a select set of levers from the tool to output the overall cost reduction for a 13-unit order book.

The results of this framework should not be interpreted as definitive cost estimates. Rather, they provide a useful quantitative analysis of the relative impact of various levers on the capital cost reduction in advanced nuclear plants. Particularly, the framework quantifies the importance of large, committed order books as identified in the Advanced Nuclear Liftoff Report. Placing larger order books can help spread the costs (and therefore, financial risk) across several plants and owners. This helps overcome the initial investment impasse stemming from the expected cost overruns with the first plants.