# From Design to Deployment: Project Management

# for Successful Project Completion

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**Abstract**

Successful completion of a new nuclear power project requires not only a competitive design, but a right project management strategy and its early prioritization. While it is natural for technology developers to prioritize research, development, and perhaps even testing/demonstration of their design, accounting for certain “implementation” variables early in the process would lead to more realistic evaluation of both project financing and timeline. From the decades of building and operating nuclear power plants - and complex, expensive, and long-term projects in other industries - we can distill the “implementation” variables that should be incorporated into development of the overall project management strategy. The paper will identify some of these variables from previous nuclear power projects, analyze how they may influence deployment of advanced reactor technologies, like Small Modular Reactors, and suggest what technology vendors and customers/owners can do to minimize the risk from such variables to facilitate a successful completion of a new nuclear project, including those based on the advanced reactor technology. The paper is based on the authors’ personal insights gathered over the years of legal practice focused on nuclear power projects, including many conversations with stakeholders in nuclear industry. As such, the paper is not meant to be a comprehensive review of project managements issues encountered around the world in nuclear newbuild, but a brief outline of practical lessons-learned that may be of benefit to those considering launching their own new nuclear power projects and programs.

## INTRODUCTION

Initial conversations about new nuclear power projects, whether it is a conversation with a technology provider or a potential owner entity (“**Owner**”) in an embarking country, tend to focus on technology. Owners seek to explore what reactor technologies are available and may be able to meet the targeted production capacity of electricity in a safe, secure, and efficient manner. Technology developers and contractors, the likely interlocutors in such conversations, provide dazzling presentations of their technology with graphics, schematics, and assessments. However, it is not technology itself that most concerns the financial institutions, high-level decision makers, or the public (aside from the perception of a linkage between technology and accidents, such as Chernobyl, Three Mile Island, or Fukushima Daiichi). Rather, the cautious and even negative perceptions at the base of apprehension toward new nuclear power projects are focused on project development issues, like cost and budget overruns. Yet, these project development issues are usually considered by technology developers, contractors, and Owners at the stages later than what may be prudent for an efficient implementation of a new nuclear power project.

The foundation for a successful nuclear power project is established at the earliest stages of project and technology product development. Construction schedule delays and cost overruns pose a risk to the lifecycle cost of a nuclear power project. These project risks can be mitigated through applying best practices during the project development and construction, and even early product development phases. The long history of commercial operation of nuclear power plants, demonstrating a remarkable capacity of nuclear industry to learn from each other’s mistakes, provides a wealth of lessons-learned in nuclear newbuild project development.

The paper suggests that the best practices should be gleamed from these lessons-learned and incorporated into the project development as early as possible; for the Owners, such consideration would be no later than technology selection; and for technology developers and contractors, lessons-learned may be incorporated even as early as development of the technology product, i.e. SMR power plant. The paper provides an overview of issues that have consistently emerged during construction of nuclear power projects over the past several decades to demonstrate that these issues are not related to technology itself, but rather to project management and delivery approaches; and highlights how such issues may be applicable to deployment of Small Modular Reactors (“**SMRs**”). Specifically, the paper provides actual examples of the nuclear power projects to highlight that the most frequently encountered issues are delays and cost overruns during construction, cost and performance issues after commercial operation, and financial issues related to external markets and business models. Finally, the paper concludes by stressing that the issues and lessons-learned are not related to the technological features of a specific design, but rather to the process, which can be improved with a deliberate effort to actually *learn* the lessons. Applying these lessons to deployment of SMRs is likely to facilitate their deployment.

## lessons Learned from Previous Projects

### Delays and cost overruns during construction

#### Reasonable construction schedule and budget

Reasonableness – rather than external considerations - in development of a construction schedule and budget are key to ensuring successful completion of a new nuclear power project that meets the scope, budget, and schedule. The two main players in a new nuclear construction project, an Owner of the new nuclear project and a technology developer/contractor performing the services, are likely to consider a variety of factors when developing a construction schedule and budget. Many of these factors may be external considerations unrelated to the project itself, however, in a new nuclear power project time-to-build is closely correlated with the cost-to-build. The projects that experience long delays are also likely to experience cost overruns. While there are financial motivations and incentives to limit time-to-build as much as possible, setting an inflexible and unattainable project schedule based on external consideration may create pressures that ultimately result in higher costs and longer time-to-build. The same is true with setting an overly ambitious project budget. While modelling for the cost of a nuclear power project can be difficult, comparisons with plants in similar countries, conditions, and circumstances must be done for the best approximation of the plant construction budget; and, indeed, must be requested by Owner from the bidders at the initial stages of procurement process. This is especially true with first-of-a-kind (“**FOAK**”) projects, such as those based on the yet-untested SMR technology, which due to their novelty are likely to require more flexible construction schedules and budgets. The burden of determining a reasonable schedule and budget, however, should be borne by both Owners and technology developers and contractors.

#### Final design

Starting construction before completing a final power plant design and detailed engineering exacerbates the risk of increased costs and schedule delays. Nuclear power projects that start construction before the completion of a final design and detailed engineering are correlated with increased time-to-build and cost-to-build outcomes. This is due to re-designs and re-builds as well as delays in receiving regulatory approvals for revised designs. For example, in the case of Olkiluoto-3, both regulators and the project development team have reported that a complete design would have helped to mitigate against the multi-month delay before starting construction. [1] The Olkiluoto-3 reactor was developed by a consortium formed by Areva and Siemens for Teollisuuden Voima Oyi (“**TVO**”), where Areva supplied the nuclear island, the digital control system, first fuel core, various civil works and coordinated the overall project; and Siemens built the turbine island and supplied the turbine generator set. The project was notoriously plagued by delays. One source of the delays was starting construction before completing the design and detailed engineering. The intent was to “fast track licensing” by submitting not final/finalized design and detailed engineering. However, as the design and engineering were revised, Olkiluoto-3 subcontracts had to re-work parts of the project that were completed based on then-outdated blueprints, and the regulatory approvals were delayed due to incomplete and changing design documents. [2] While there are dozens of SMR designs around the world in various stages of development, there are few, if any, SMR designs that can boast completed design and engineering. The internal pressures within SMR technology companies to generate profits and external drivers of high demand from customers is a combination that will likely lead to some SMR project commencing construction without completing final detailed design and engineering. Such an approach, however tempting, can and should be avoided by both Owners and technology developers/contractors to ensure that the new nuclear projects based on a FOAK technology do not create an unfavourable precedent.

#### Project management of cooperation, coordination, and interface issues

Interface challenges are ubiquitous in a large construction projects, including new nuclear power projects . In a new nuclear power project there are many contractors, subcontractors, supply chain vendors working together to implement the complex endeavour of launching a nuclear power plant. The Lungmen 1 & 2 project in Taiwan provides an extreme example of interface issues that can significantly stall the project. Taiwan Power Corporation, owner of Lungmen 1 & 2, had initially planned to secure one main contractor for the engineering, procurement, and construction of the units. However, due to some factors, including widespread political opposition, the project was structured so that GE would supply the reactor, Mitsubishi the turbines, and other contractors would provide additional services. [4] In total, more than 500 separate contracts supported the project. As a result, confusion and delays, compounding the work stoppages caused by political opposition, led to the project being mothballed in 2021. [5] SMR developers are likely in their initial stages of developing their supply chains. As the SMR designs mature and deploy at scale, the supply chains will grow around them with time. Currently, however, the vendors are not able to provide integrated services/products to support the novel technology and many of these services/products would have to be customized. Thus, as SMR developers are considering their supply chain, it may be worth exploring opportunities for long-term cooperation with a small number of such partners to avoid issues that plagued the Lungmen 1 & 2 project . In turn, Owners considering new nuclear power projects based on an SMR technology, should request the opportunity to evaluate the supply chain in advance.

#### Lead project manager and project management team

A skilled and experienced project manager who can manage contractors and subcontractors is critical to navigating the interface challenges as well as coordination issues. A large number of contractors and subcontractors (even if they are limited through a prudent supply chain management), each with their own organizational cultures and approaches, may lead to difficulties in cooperation, which will likely result in project delays. Leadership by a project manager that has experience managing large-scale projects (whether nuclear or not), large number of subcontractors, the complexities of the large project, and implementing finalized design, has been positively correlated with completion of the new nuclear power project on time and on budget. For a new nuclear power project based on an SMR technology an experienced project manager would be key to resolving the anticipated and unanticipated issues that will inevitably arise during implementation of a FOAK project.

#### Human resources and safety culture

Workforce and safety culture issues are also positively correlated with increased costs and construction times. Due to highly-specialized expertise, knowledge and skills required for a (large) nuclear power projects, limited human resources has been one of the major issues for the nuclear newbuild projects, like Olkiluoto-3, in the past and is likely to be even more so in the future. Availability of skilled and experienced workers is exacerbated by the lack of a consistent stream of new nuclear power project constructions over the past several decades; and is a particular concern for new comer countries that have had no experience with nuclear power. In addition to the required specialized knowledge, skills and experience, safety culture amongst the workforce can pose a risk to the NPP lifecycle costs as well. For example, in Olkiuoto-3 the Finnish nuclear safety regulator publicly noted that lapses in safety culture resulted in project quality issues, which ultimately led to increased costs and schedule delays. [6] New nuclear power projects based on SMR technology will likely encounter issues of availability of skilled and knowledgeable workforce. Due to novelty of designs and lack of workforce with experience operating plants based on these designs, initially workforce may have to be trained by technology developers. However, the risk that shortage of highly specialized skilled workers will contribute to increase of project costs and schedules may be mitigated in nuclear newbuild projects utilizing SMR technology, as it may be possible to localize such risk to the manufacturing/production facilities. Furthermore, while the safety culture issues will remain important, the inherent safety features of SMRs and the likely smaller workforce that may be required to operate the SMR plant once installed, would decrease likelihood of safety culture lapses during the operation.

### Cost and Performance issues after Commercial Operation

#### Project assumptions and financial projections

Once a nuclear power plant is operational, operating performance issues may arise due to flawed assumptions based on financial projections and maintenance issues. The standard metric for the operating performance of nuclear power plants is the annual capacity factor (“**CF**”), calculated by dividing the actual power produced by the plant for the year by the total possible power output for that year. A higher CF implies a higher GWh output, higher revenue, and the operating costs of the nuclear power plant spread across more GWh. Analyses and financial projections for nuclear power plants usually assume a 90% CF. However, a lifetime assumption of a 90% CF for a nuclear power plant is ambitious and for many nuclear power projects, too high. World Nuclear Association assessed that global average capacity factor in 2023 was 81.5%, which was an increase from the global capacity factor of 80.4% in 2022. [7] While the average CF tends to increase over time, there are still variations in the CF depending on the location of the nuclear power plant and the age of the plant. As such, financial projections and analyses should seek to compare the new projects to existing projects in the same country, climate, and of a similar vintage. While it is feasible that a new nuclear power project could achieve an average lifetime CF of 90%, this should not be a baseline assumption. Scenarios for the CF in the financial analysis should not consider a CF greater than 90% and should include scenarios for cases that include an average CF as low as 80% and annual levels that are as low as zero to account for planned and unplanned outages.

While outages are included in the financial projections for a new nuclear power project, the practice of including prolonged outages in the scenario analysis should extend beyond analyzing the base scenario. For example, the Browns Ferry nuclear plant in Atlanta, United States, experienced prolonged outages of its three units in the early through the mid-1980s as the first unit’s outage lasted more than twenty-one years, the second unit’s outage lasted more than six years and the third unit’s outage lasted more than ten years. [8] Since 2007 all three units have been operating at a reasonably good operating performance, however, the years of prolong outages impacted the average lifetime CF of the project. In case of SMR’s, due to lack of operating data, even establishing a base scenarios for financial projections is purely speculative. However, the lessons-learned from operation of large nuclear power plants indicate that the CF that is likely to provide a more realistic estimation to those that will be calculating costs during operations, is significantly lower than 90%.

#### Maintenance issues

Maintenance issues may lead to prolonged outages or early closures of nuclear power plants. Major maintenance activities for an operational nuclear power plant may cost more and take longer than expected. Financial projections for nuclear power plants should include such scenarios of prolonged outages and increased maintenance costs. For example, the Crystal River nuclear power plant in Florida was retired early as the maintenance issues snowballed, and so did their costs: the steam generators of the plant had to be replaced during a refuelling outage; to replace the steam generators, a temporary access hatch was cut into the containment building; and when cuts for the temporary access hatch were made, the concrete containment structure cracked and delaminated. The total estimated repair cost was between $1.5 – 3.4 billion and resulted in early retirement of the plant . [9] The need for contingencies (including financial) to manage the risks associated with maintenance would be especially important for SMR plants. Although the SMR developers estimate that certain inherent design features will decrease the frequency of maintenance and higher enrichment assay of fuel considered for many SMR designs may decrease the frequency of refuelling, there is lack of operating experience to substantiate such estimations as of yet. Thus, for the first few deployments of FOAK designs, prudent project management approach would be to include sufficient (even if generous) contingencies.

### Financial Issues related to External Markets and Business Models

#### Unregulated market issues

The transition from the traditional government utility model to a privatized industry has posed specific challenges for nuclear power plants in determining the level and certainty of revenue. Nuclear power plants have high up-front capital costs, approximately 50-70% of levelized electricity generating costs, but low operating costs, around 20-30% of levelized electricity generating costs. [10] Financial models for nuclear power projects must account for liabilities such as nuclear waste, management, and disposal as well as decommissioning. The high capital costs and long construction periods require longer debt repayment terms. Historically, direct or indirect government funding or corporate balance sheets funded nuclear power plant construction. Now, new project structures and new sources of finance are available, including merchant nuclear power plants, build own operate projects, and cooperative models. The difference between a merchant nuclear plant and a regulated/government nuclear power plant is that there is no certainty of revenue for the merchant power plant. This difference raises two issues for merchant nuclear power plants: the first is the financial distress and early retirement of U.S. merchant nuclear plants as a result of electricity industry restructuring and the second is the difficulty of attracting investors to build new merchant nuclear power plants. In 2014 multiple U.S. merchant nuclear power plants closed because the operating costs of the plants could not compete in the electricity market, where the boom in shale natural gas led to lower cost electricity. [11]

The closure of these plants has some key lessons to be learned. First, electricity markets are unpredictable. Even with improvements in the cost and performance of nuclear power plants, the U.S. merchant power plants experienced financial losses due to external market factors. Second, long-term projections on the electricity market may be incorrect; and long-term projections for a nuclear power plant must take this uncertainty into account. Third, long-term revenue security is important for nuclear power projects to hedge against the electricity market risk. Mechanisms to ensure long-term revenue security include long-term power purchase agreements, long-term hedge contracts, or floor price contracts. Lastly, allowing for flexibility in plant operation status is important and valuable to nuclear plants weathering electricity market fluctuations.

These lessons were learned based on performance of large nuclear reactors. However, they are relevant for those looking to sustainably deploy their SMR plants. For instance, external market factors and uncertainty of long-term projections are important risks to be considered for deployment. Unlike large nuclear power reactors, the SMRs are likely to be better positioned to mitigate them. Due to their size and possibility of localized deployment, SMRs may be deployed to meet energy demands of a different kind of customer than those serviced by the large nuclear reactors. In the United States, the Artificial Intelligence and Data Centres have expressed interest in buying energy from SMRs. Microsoft, Google and Nucor have issued a request for information from SMR developers, based on a demand pooling model, to obtain a sustainable source of high volumes of energy and jump start the deployment of SMR technologies. [12] These companies aim to conclude power purchase arrangements with SMR developers, thereby providing the technology companies with a secure source of profits not dependant on fluctuations of the electricity market as a whole. However, the flip-side of such an arrangement is that the SMR technology companies would likely be dependent on only a few sources of potential profits, rather than a larger market.

## Discussion and Conclusion

The nuclear power projects completed over the past several decades highlight several lessons to be learned and good practices to be incorporated into project management approaches at the earliest stages of a new nuclear power project. These include having a reasonable construction project schedule and budget, using a complete final design and engineering before commencing construction, effective project, maintaining an experienced workforce with a strong safety culture. Albeit these were learned from construction and operation of large nuclear power reactors, they remain applicable for nuclear power project based on the emerging SMR technologies. Indeed, due to their inherent features, SMRs may be better positioned to mitigate some of the risks exposed by the lessons-learned. Other risks, may be exacerbated due to novelty and lack of operating experience with the emerging SMR power plants. However, what is the key lesson to be learned, is that integrating considerations of these best practices into the commercial conversations between SMR developers and Owner entities at the earliest stages of a potential transaction, would facilitate a completion of an SMR nuclear power project on time and on budget.

ACKNOWLEDGEMENTS

The authors wish to express gratitude to their clients and colleagues at Hunton Andrews Kurth LLP for generously sharing their experience and time in assistance with the paper, particularly Douglas Dua and Colleen Grygier. The authors also wishes to thank Helen Cook for her contribution to the insights reflected in the paper. Finally, the authors would like to express their appreciation to Hunton Andrews Kurth LLP for supporting the development and presentation of the paper.

References

[1] Lack of complete design blamed for problems with Olkiluoto-3, Nucleonics Week (17 May 2007).

[2] LAAKSONEN, J., Lessons learned from Olkiluoto 3 plant, Power Engineering (2010), https://www.power-eng.com/news/lessons-learned-from-olkiluoto-3-plant/#gref.

[3] Nuclear power in Taiwan, World Nuclear Association (2024), https://world-nuclear.org/information-library/country-profiles/others/nuclear-power-in-taiwan.

[4]GE seeks arbitration over Lungmen payments, World Nuclear News (14 December 2015), https://www.world-nuclear-news.org/Articles/GE-seeks-arbitration-over-Lungmen-payments.

[5] Nuclear power in Taiwan, World Nuclear Association (2024), https://world-nuclear.org/information-library/country-profiles/others/nuclear-power-in-taiwan.

[6] STUK begins investigating construction delay at Olkiluoto-3, Nucleonics Week (2 March 2006); Olkiluoto-3 base slab pour delay not expected to impact end date, Nucleonics Week (6 October 2005); Completion of Finland’s 5th nuclear reactor further delayed by 1 year, Associated Press (11 July 2006).

[7] Global Nuclear Industry Performance, World Nuclear Association (2024), https://world-nuclear.org/our-association/publications/world-nuclear-performance-report/global-nuclear-industry-performance.

[8] TVA Restarts Browns Ferry Unit 1, Tennessee Valley Authority (22 May 2007), https://web.archive.org/web/20070615003835/http://www.tva.gov/news/releases/aprjun07/restart.htm.

[9]Duke Energy plans to decommission retired Florida nuclear plant by 2027 – nearly 50 years sooner than originally scheduled, Duke Energy (30 May 2019), https://news.duke-energy.com/releases/duke-energy-plans-to-decommission-retired-florida-nuclear-plant-by-2027-nearly-50-years-sooner-than-originally-scheduled#:~:text=CRYSTAL%20RIVER%2C%20Fla.,no%20impact%20on%20customer%20bills.

[10] KOZERACKI, J., VLAHOPLUS, C., Advanced Nuclear Pathways to Commercial Liftoff (March 2023).

[11] Lower power prices and high repair costs drive nuclear retirements, Energy Information Administration (2 July 2013), https://www.eia.gov/todayinenergy/detail.php?id=11931.

[12] PETERSON CORIO, A., CALDERON, D., One small step for RFPs, one giant leap for clean energy, Google Cloud Blog/Sustainability (15 March 2023), https://cloud.google.com/blog/topics/sustainability/a-new-approach-to-clean-energy-power-purchasing-agreements.