Avencore

MASTERING NUCLEAR CAPEX INVESTMENTS: 3 GUIDING PRINCIPLES FOR NUCLEAR LEADERS

Nuclear operators, EPCs, and industrial players, in their quest to meet growing energy demand, are undertaking large-scale CAPEX investments to secure long-term operation of existing fleets, build new reactors, or develop advanced nuclear technologies like Gen III and Gen IV Reactors. Such investments are critical to achieving their long-term strategic goals, including securing low-carbon baseload power, extending plant lifetimes, or capitalizing on renewed government and private support for nuclear energy. These investments often require commitments of 10 or more years.

These large-scale investments are not routine projects. They disrupt business as usual and require skill sets that are often unavailable or underdeveloped in-house. Navigating the nuclear construction ecosystem — shaped by strict regulatory requirements, specialized supply chains, and first-of-a-kind technical challenges — may prove particularly daunting to teams that rarely face such large and complex projects.

However, executing with excellence is not optional. Given the formidable amounts invested, and the hard lessons from projects like Vogtle Units 3 & 4 or Flamanville (France) — where cost overruns reached multiples of initial estimates — any financial, schedule, or technical deviation may result in substantial ROI losses and hinder the overall energy strategy.

THIS ARTICLE EXPLORES 3 ESSENTIAL GUIDING PRINCIPLES THAT HELP LAY THE FOUNDATION FOR SUCCESSFUL NUCLEAR CAPEX EXECUTION.

1 ANTICIPATE THE IMPACTS OF LARGE NUCLEAR CAPEX PROJECTS ON YOUR ORGANIZATION

Delivering on a large nuclear CAPEX project will disrupt established ways of working. Teams are not likely to be on time and on budget while meeting the required safety and quality standards if they do not adopt an appropriate operating model and organization. The challenge is amplified when projects involve 50 to 500+ stakeholders — often from diverse professions and backgrounds, including regulators, EPCs, subcontractors, and specialized nuclear vendors — who must collaborate intensively under unfamiliar conditions.

To position a project for success and undergo the required changes, senior management may:

STRENGTHEN THEIR CAPABILITIES

Ensuring individuals can deliver on their roles and responsibilities will help prevent any shortcomings down the road. In the nuclear sector, capability gaps are particularly consequential, since regulatory non-compliance or quality failures can halt projects entirely. Critical capabilities must be identified and explicitly detailed, expectations stated clearly, and training provided where needed.

Example of capabilities:

- Project management
- Stage-gate governance
- Value-based planning & design
- Continuous improvement
- Risk identification and management
- Procurement & supply chain
- Safety management
- Rapid quality response
- Digital ways of working

A previous Avencore engagement:

When a major North American nuclear manufacturer faced a rapid production ramp-up for a large Canadian refurbishment program, underdeveloped capabilities in planning, scheduling, performance measurement, QA, and staff management were identified as critical constraints. By systematically assessing and building organizational readiness before scaling execution, the supplier achieved a 4x increase in production within 17 collaboration weeks and subsequently laid the groundwork to a 7x throughput improvement. Getting the organization ready before ramping up execution was the critical unlock.

SET UP THE RIGHT ORGANIZATION

Ensuring individuals can deliver on their roles and responsibilities will help prevent any shortcomings down the road. In the nuclear sector, capability gaps are particularly consequential, since regulatory non-compliance or quality failures can halt projects entirely. Critical capabilities must be identified and explicitly detailed, expectations stated clearly, and training provided where needed.

- **Structure project execution and adapt to the unique project and nuclear-specific challenges and constraints**
- **Formalize Roles & Responsibilities** and deliverables for each stage, including regulatory and customer oversite interfaces, ensuring that organization silos do not impede capability
- **Build quantitative staffing plans** to steer the project and set the right drumbeat, while ensuring leadership stays focused on the overall project, not firefighting
- **Establish routines & governance** to steer the project and set the right drumbeat, while ensuring leadership stays focused on the overall project, not firefighting
- **Monitor progress** through KPIs that encourage transparency, accountability, and a result-oriented culture

MAP ALL STAKEHOLDERS AND MANAGE THEM CLOSELY

- **Map key stakeholders** including regulators, end-users, investors, legal, procurement, and the nuclear supply chain and understand their incentives for the project
- **Establish 'One Shared Story.'** Communicate on 'why,' 'need for change,' and 'goals we will achieve together' that consider the motivations of each stakeholder
- **Discuss project expectations**, including what success looks like, how and when to involve each stakeholder, and challenges foreseen
- **Keep stakeholders continuously involved** and measure concrete impact — set up pulse surveys to maintain momentum

IMPACT ON PROJECT SUCCESS

WINNING BEHAVIORS ENABLED BY A STRONG ORGANIZATION.

2 START WITH THE BASICS - ALIGN ALL STAKEHOLDERS ON REAL NEEDS BEFORE SELECTING A SOLUTION

No two CAPEX projects are identical. Even when organizations leverage standardized reactor designs or reference projects, large nuclear investments have unique specificities — site conditions, regulatory environments, workforce availability, grid integration constraints — requiring tailored solutions. The standardization promise of new nuclear technologies (e.g., SMRs) does not eliminate the need for rigorous requirement definition upfront.

Four foundational documents structure the needs definition process in nuclear CAPEX:

FUNCTIONAL PROGRAM

A key document to define the functional and operational requirements to be fulfilled by the investments, based on user needs.

REQUIREMENTS VALIDATION GATE

Formal confirmation by all relevant stakeholders — including the regulator where applicable — to ensure that the defined requirements are aligned with user expectations, project constraints, and strategic objectives.

BASIS OF DESIGN

Translation of validated needs into technical criteria and design assumptions — in nuclear, this step carries particular weight given the cost and regulatory implications of late-stage design changes.

ENGINEERING VALIDATION

As design assumptions are determined, they must be validated as much as possible. While unwelcome discoveries during construction are often expected, the cost and schedule implications for large nuclear CAPEX projects can lead to loss of asset, failure of project, or loss of contracts.

A common mistake is to jump into execution without verifying that real needs are solved by the solution. The consequence: the solution is often not optimized for long-term operation, cost, schedule, or quality. In nuclear, this risk is compounded by long regulatory approval cycles and the immense difficulty of course correcting during construction without significant cost and schedule impact. In our experience, an inaccurate and misaligned definition of business needs ranks among the top five causes of project failure.

Another common risk — particularly prevalent in programs managing many first-of-a-kind (FOAK) or 'first in a long while' projects — is that critical needs or key hypotheses that should have been locked in early are still challenged during the basic design or even detailed design phase. For example, a US nuclear operator managing a large reactor upgrade portfolio across multiple sites experienced costly critical-path delays during outages due to poor inter-site coordination and underdeveloped risk management practices that allowed hundreds of unidentified risks to propagate. Challenging critical needs or hypotheses during the design phase can lead to waste, lost momentum, and frustration among teams — and in the nuclear context, these consequences are amplified by the regulatory and safety stakes involved.

Four foundational documents structure the needs definition process in nuclear CAPEX:

- **Map comprehensive requirements:** Document and validate commercial, technical, operational, and regulatory requirements across all stakeholder groups — including the NRC or equivalent authority
- **Build business scenarios:** Develop multiple scenarios to analyze sensitivity of each criteria and assumption on the execution plan, such as unknown site conditions, supply chain dynamics, human capital requirements, and regulatory hurdles
- **Engage key stakeholders:** Involve end-users, key suppliers, and the regulator as early as possible. In nuclear, early regulatory engagement can prevent costly redesign later
- **Balance innovation and proven solutions:** Strike the optimal balance between licensed, proven technologies and innovative alternatives (e.g., digital instrumentation, advanced manufacturing) that may offer competitive advantages without triggering lengthy re-qualification processes

A previous Avencore engagement:
A large operator managing multiple sites identified hundreds of previously unrecognized or improperly managed risks impacting outage schedules and CAPEX programs. By reassessing requirements, governance, and risk management processes, the organization significantly improved its ability to execute projects on cost and schedule.

IMPACT ON PROJECT SUCCESS

BUSINESS AND INDUSTRIAL OBJECTIVES ARE SUPPORTED BY THE RIGHT TECHNICAL CHOICES

3 DESIGN-TO-VALUE

OBJECTIVE

Getting the best value out of design choices to lower the **Total Cost of Ownership** and increase **ROI**. This drives benefits across both:

- **The project:** reducing cost and time of the nuclear CAPEX execution
- **The operations:** maximizing plant availability, expanding plant life time, and improving maintainability within regulatory constraints

To make the Design-to-value approach successful:

Start with a robust baseline (Cost, Schedule, and Risk). Building a strong baseline will take time and energy, but it should be considered as an investment. In nuclear, low maturity estimates are a root cause of the chronic cost overruns observed in Western megaprojects. Benchmarking against reference projects (e.g., global new nuclear builds), expert assessment, parametric models, and supplier quotes are levers to ensure a comprehensive baseline.

Optimize schedule alongside cost. For nuclear CAPEX programs, cost and schedule are strongly linked and should be addressed simultaneously. Each day of delay on a nuclear outage or construction project carries significant revenue or cost implications, before considering the local or regional grid impacts. Involving suppliers and contractors early helps identify risks and opportunities — particularly given the fragility of the specialized nuclear supply chain — while allowing the parties to grow as a team..

From cost-down to value-improvement. Successfully employing Design-to-Value in nuclear unlocks not only cost savings but also additional value from the CAPEX investment by fostering teams' creativity — for example, using analysis to explore both evolutionary improvements (alternate engineering approaches, process redesign) and disruptive ideas (advanced manufacturing, modularization). As an additional benefit, the cost savings achieved can be reallocated to high-value technical options — such as improved digital instrumentation or enhanced safety systems — that would otherwise have been considered too expensive.

IMPACT ON PROJECT SUCCESS

MAXIMIZED VALUE GAINED FROM YOUR CAPITAL EXPENDITURE.

KEY INSIGHTS

Effective nuclear CAPEX projects involve far more than engineering and construction activities. They require a strategic approach that aligns technical execution with business and energy objectives — while navigating the unique constraints of nuclear regulation, supply chain fragility, and public scrutiny. By leveraging the three basic guiding principles above, nuclear organizations can maximize value, reduce Total Cost of Ownership, and support long-term energy and industrial objectives

- **Position the nuclear CAPEX project as a transformation**
- **Define the need — including regulatory requirements — before selecting a solution**
- **Design-to-Value, accounting for nuclear-specific constraints and opportunities**

YOUR STRATEGIC PARTNER IN INDUSTRY

Avencore is an international consulting firm specializing in the industrial sector, driven by a passionate team of 130 experts . We serve as a strategic partner for leading global corporations, mid-sized companies, and industrial players navigating challenges in growth, competitiveness, transformation, and decarbonization — including in the nuclear sector. From strategic planning to hands-on implementation, we ensure that our solutions are both actionable and measurable. Our team possesses unparalleled knowledge of complex industrial products, systems, and organizations, allowing us to provide comprehensive support and alignment at all levels. By empowering leaders to make data-driven decisions, Avencore becomes a trusted advisor on their path to sustainable growth and performance.

OUR CAPEX EXPERTS

Nicholas O'Shea
Partner

Gautamraj Baskaran
Manager

Taylor Huneycutt
Manager