Energy Infrastructure CAPEX: Why Regulatory Risk Has Replaced Construction as the Critical Path

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Abstract

The traditional paradigm of energy infrastructure project control — centered on construction velocity, electromechanical assembly, and physical progress metrics — is no longer sufficient to protect CAPEX and investment milestones in utility-scale renewable energy projects. This article argues that regulatory permitting and grid interconnection processes have displaced construction as the primary critical path variable in Solar PV, Wind, and Battery Energy Storage System (BESS) projects across Latin America and the United States. Drawing on direct project management experience in utility-scale energy infrastructure spanning over 25 years and multiple geographies, this paper examines three strategic responses available to modern Project Directors: the adoption of dynamic, probabilistic baselines through Monte Carlo simulation; the early integration of grid operators as active technical stakeholders from the detailed engineering phase; and the structural alignment of EPC payment milestones with critical regulatory approvals to protect project cash flow. The central thesis is that profitability in energy infrastructure is no longer won during construction — it is defended during development, through the disciplined management of regulatory risk as a quantifiable CAPEX variable.

Keywords: CAPEX management, regulatory risk, grid interconnection, Monte Carlo simulation, EPC contracts, utility-scale renewables, COD, project finance, permitting, energy transition.

1. Introduction

For decades, the project management discipline in energy infrastructure was built around a straightforward premise: the project that builds fastest, wins. The critical path ran through earthmoving, transformer delivery, and electromechanical assembly. The skills that mattered were construction supervision, supply chain management, and physical progress tracking. The tools that prevailed were the Gantt chart, the earned value report, and the site visit.

That paradigm is no longer adequate for the current landscape of utility-scale renewable energy development. Across Latin America, the United States, and Europe, a structural shift has occurred: the variables that most frequently destabilize cash flows, delay Commercial Operation Dates (COD), and destroy CAPEX are not found in the construction sequence. They are found in the labyrinth of sector permits, grid interconnection queues, regulatory approvals, and technical compliance processes that must be navigated before — and during — physical construction.

This article examines this paradigm shift and its implications for modern Project Directors managing utility-scale Solar PV, Wind, and BESS projects. It is grounded in direct field experience across multiple geographies and project types, and structured around three practical strategic responses that have proven effective in protecting CAPEX and COD targets in regulatory environments of high complexity.

The central argument is simple but consequential: in modern energy infrastructure, profitability is no longer won during construction — it is defended during development. Project Directors who fail to internalize this shift will continue to produce technically excellent construction outcomes that arrive too late, cost too much money, and generate value below expectations.

2. The New CAPEX Paradigm: When Regulatory Risk Became the Critical Path

The transformation of the energy sector's critical path did not occur suddenly. It is the cumulative result of multiple converging forces: the explosive growth of renewable energy deployment, the insufficient expansion of transmission infrastructure, the increasing complexity of environmental and sector permitting processes, and the growing sophistication of grid operators' technical requirements for new generation assets connecting to the network.

In Chile, the renewable energy boom of the last decade exposed a fundamental asymmetry: greenfield solar and wind projects could be permitted and constructed in three to four years, while the transmission infrastructure needed to evacuate that energy required eight to ten years of permitting, rights-of-way acquisition, and regulatory approvals. The result was a systemic curtailment crisis that cost developers billions in unrealized revenues and fundamentally altered the risk profile of every project in the pipeline (International Energy Agency, 2023).

In the United States, the Federal Energy Regulatory Commission (FERC) interconnection queue has become the defining bottleneck for renewable energy development. As of 2024, over 2,600 gigawatts of generation and storage capacity were awaiting interconnection approval — a backlog representing approximately five times the total installed generation capacity of the country (Lawrence Berkeley National Laboratory, 2024). Projects with technically complete and financially viable business cases routinely wait five to seven years for interconnection approval.

In Mexico, the National Electric System Operator (CENACE) faces similar pressures, with interconnection processes complicated by regulatory uncertainty, infrastructure constraints, and the institutional limitations of a grid operator managing an energy transition of unprecedented speed and scale (Mexico Energy Partners, 2024).

The common thread across all these geographies is clear: the construction of a renewable energy project is no longer the difficult part. The difficult part is navigating the regulatory and institutional environment that determines whether — and when — that project can connect to the grid and begin generating revenue. Consequently, Project Directors who treat these regulatory processes as administrative tasks to be managed by legal teams will systematically underperform relative to those who treat them as critical path activities to be actively managed from day one.

3. Three Strategic Responses for the Modern Project Director

The recognition that regulatory risk has become the primary CAPEX threat is necessary but insufficient. What matters for Project Directors is how to translate this recognition into practical management strategies that protect investment timelines and cash flows. Three responses have proven consistently effective across different project types and geographies.

3.1 Dynamic Baselines: From Static Gantt to Probabilistic Scheduling

The traditional project schedule presents each activity with a fixed duration, a fixed start date, and a fixed finish date. This deterministic approach is adequate for activities where the duration is well understood and controllable — such as concrete pouring, cable pulling, or equipment installation. It is entirely inadequate for regulatory activities, where the duration depends on the behavior of external institutions, the completeness of submitted documentation, the interpretation of technical standards, and the processing capacity of regulatory bodies that operate on their own timelines, independent of the project's schedule.

A project team that models the environmental impact assessment approval as a fixed six-month activity is not planning — it is expressing a hope. The same activity might take four months with a complete and well-prepared submission, or fourteen months if the regulatory body requests additional studies, if community opposition triggers a review process, or if internal processing delays accumulate within the institutional queue.

The appropriate tool for modeling regulatory uncertainty is probabilistic scheduling, specifically Monte Carlo simulation. Rather than assigning a single duration to a regulatory activity, the project team defines a range — typically an optimistic estimate, a most likely estimate, and a pessimistic estimate — and runs thousands of simulations to generate a probability distribution for the project's completion date. The result is not a single COD date but a range of dates with associated probabilities: the project has a 50% probability of achieving COD by a certain date, an 80% probability of achieving it three months later, and a 90% probability of achieving it six months later (Hulett, 2011).

This approach has two critical advantages for CAPEX management. First, it provides a realistic basis for financial modeling: rather than committing to a COD date based on an optimistic regulatory scenario, the project's financial model can be stress-tested against the full range of probable outcomes. Second, it identifies the regulatory activities that have the greatest impact on schedule uncertainty — the activities where mitigation efforts will generate the highest return in terms of schedule risk reduction.

The practical implication for Project Directors is straightforward: no project of USD $50M or more should be presented to a board or a financial institution with a deterministic schedule for its regulatory activities. The schedule should show the probabilistic range, the key regulatory milestones, and the confidence intervals associated with each. A board that approves a project based on a P50 COD date — without understanding that the P90 date is six months later — is making a decision based on incomplete information.

3.2 Grid Operators as Active Stakeholders: Early Engagement as CAPEX Protection

In the traditional project management model, the grid operator or national electrical coordinator appears in the project's stakeholder map as an external authority — an entity to be complied with rather than collaborated with. The project team submits documentation to the grid operator according to the required timelines, responds to observations when they are received, and hopes that the approval process concludes before the construction program runs out of schedule buffer.

This passive approach is structurally inadequate for the complexity of modern grid connection processes. Grid operators in mature electricity markets — whether Chile's

Coordinador Eléctrico Nacional, FERC and the regional transmission organizations in the United States, or Red Eléctrica de España — apply increasingly sophisticated technical requirements to new generation assets connecting to the network. These requirements address protection systems, power quality, frequency response, reactive power capability, SCADA integration, and commissioning protocols. Each requirement must be demonstrated through documentation and testing, and each documentation package must satisfy the technical reviewers at the grid operator before the next stage of the approval process can proceed.

Projects that first engage substantively with grid operator technical requirements during the detailed engineering phase — or worse, during construction — systematically discover that their designs require modifications to satisfy requirements that were knowable from the beginning of the project development phase. These modifications generate rework, procurement changes, and schedule delays that are entirely preventable (IRENA, 2023).

The alternative is to treat the grid operator as an active technical stakeholder from the earliest stages of project development. This means engaging with the grid operator's connection requirements during the pre-feasibility study, incorporating those requirements as binding technical constraints in the basic engineering phase, verifying compliance in the detailed engineering phase, and developing the commissioning plan in close coordination with the grid operator's technical team — not as a document to be submitted three months before COD, but as a living technical framework that evolves alongside the project's engineering development. This proactive approach also enables the project team to anticipate potential regulatory changes during the pre-construction phases, reducing the risk of costly redesigns and COD delays.

The CAPEX implications of this approach are significant. A project that discovers a protection system non-compliance during the commissioning phase must redesign and procure replacement equipment, modify installation work already completed, and repeat commissioning sequences — all while the project sits on the grid operator's queue without a connection date. The same non-compliance, identified during basic engineering, requires only a design revision. The cost differential between these two scenarios can range from hundreds of thousands to millions of dollars, depending on the nature of the required modification.

3.3 Regulatory-Linked Payment Milestones: Aligning EPC Contracts with Regulatory Reality

The third strategic response addresses the contractual architecture of EPC contracts — specifically, the design of payment milestone structures that protect the project owner's cash flow when regulatory timelines do not conform to the construction schedule.

In a standard EPC contract, payment milestones are linked to physical construction progress: mobilization, foundation completion, structural steel erection, equipment installation, energization, and COD. This structure assumes that physical progress and regulatory progress are aligned — that when the project is ready to energize from a construction standpoint, it will also be ready to energize from a regulatory standpoint.

This assumption is increasingly false. Projects routinely achieve mechanical completion — the point at which all physical construction is complete — while still awaiting the final grid connection approval from the regulatory authority. During this period, the EPC contractor has fulfilled its construction obligations, but the project cannot generate revenue. The owner is paying financing costs, operating costs, and often penalty provisions to offtakers who expected delivery by a certain date.

A more sophisticated payment milestone structure addresses this misalignment by linking specific milestone payments to regulatory approvals rather than exclusively to physical construction progress. For example, a payment tranche might be linked to the receipt of the environmental impact assessment approval, rather than to the start of civil works. Another tranche might be linked to the grid operator's preliminary approval of the connection agreement, rather than to the installation of the substation equipment.

This structure achieves two objectives simultaneously. It provides the EPC contractor with a financial incentive to actively support the regulatory process — rather than treating it as the owner's problem — because contractor revenues are partially contingent on regulatory milestones that the contractor can influence through timely and complete documentation delivery. And it protects the owner's cash flow by deferring payment obligations to milestones that are aligned with the project's actual revenue-generation timeline (FIDIC, 2017).

The implementation of this approach requires sophisticated contract drafting and a willingness by the owner's legal and commercial team to negotiate payment structures that EPC contractors may initially resist. However, the negotiating leverage available to owners who have clearly defined regulatory milestones and realistic timelines — and who can demonstrate to contractors how regulatory-linked payments protect both parties from the cash flow consequences of regulatory delay — is greater than many owners realize.

4. Implications for Project Portfolio Management

The three strategic responses described above are most powerful when applied not just to individual projects but to portfolios of projects managed simultaneously across different geographies and development stages. Project Directors operating at the portfolio level face an additional challenge that individual project managers do not: the interaction effects between projects competing for the same regulatory resources, the same grid operator attention, and the same CAPEX allocation from the corporate level.

At the portfolio level, the most significant risk is what practitioners in the field have termed the 'Watermelon Effect': projects that appear green in portfolio-level reporting — on schedule, within budget, progressing normally — while concealing internal red conditions that have not yet surfaced in formal reports. Regulatory delays, technical compliance issues, and interface management failures are systematically underreported in standard progress reports because project teams, under pressure to demonstrate progress, interpret ambiguous situations optimistically.

The solution requires portfolio-level governance mechanisms that make optimism bias structurally difficult: standardized regulatory risk registers that require explicit probability and impact assessments for each pending approval; early warning indicators tied to regulatory milestones rather than physical progress; and portfolio review processes that explicitly ask project teams to identify the regulatory assumptions they are most uncertain about, rather than simply reporting the current status of known approvals.

Organizations that master this level of portfolio governance will not eliminate regulatory risk — that is not possible in complex institutional environments. But they will systematically detect regulatory problems earlier, respond more effectively, and make better CAPEX allocation decisions across their project pipeline.

5. Conclusion

The energy transition has created an unprecedented challenge for the project management profession: managing assets of increasing technical complexity in regulatory environments of increasing institutional complexity, under financial pressure that leaves little margin for the kind of regulatory surprises that were once treated as acceptable project risks.

The Project Directors who will lead the next decade of renewable energy development are not those who can build the fastest. They are those who can navigate the regulatory environment most skillfully, who treat grid operators as technical collaborators rather than administrative gatekeepers, who model uncertainty probabilistically rather than deterministically, and who design contracts that align financial incentives with the regulatory realities of the markets in which they operate.

The hard engineering of renewable energy projects — the design of inverters, the installation of trackers, the commissioning of protection systems — is increasingly well understood. The soft engineering of regulatory navigation, stakeholder management, and institutional risk modeling is where competitive advantage is built and where CAPEX is protected or destroyed.

Profitability in energy infrastructure is defended during development. The project management profession must internalize this reality and develop the tools, frameworks, and competencies to act on it systematically.

6. AI Disclosure

Artificial Intelligence was used to assist in the translation, formatting, and structural alignment of this article with PMWJ guidelines. The final content, technical insights, and professional experiences were reviewed and verified by the author.

7. References

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Avilio Castellano González is a Civil Electrical Engineer, PMP® and Senior Project Director with over 25 years of experience leading large-scale infrastructure projects in the Energy, Oil & Gas, and Renewables sectors. He has managed project portfolios exceeding USD $140M, specializing in the full project lifecycle from greenfield development through Ready-to-Build (RTB) to Commercial Operation Date (COD). Avilio has held executive leadership positions at prominent international energy firms, developing deep expertise in utility-scale Solar PV, BESS, and High Voltage Substation projects across Latin America and international markets. He is a recognized regional thought leader whose technical-operational analyses have reached a global audience of over 21,000 professionals, garnering more than 32,000 total impressions with a confirmed impact across eight countries (Chile, Spain, Mexico, Colombia, Peru, Argentina, Honduras, and the USA). He serves as an Award Judge for the PMI Latam Excellence Awards (2023–2025) and as a Global Reviewer for the PMI Leadership Institute (2026).

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