ELECTRIC POWER ENGINEERS

From Site Selection to Queue Submission:

The Grid-First Development Playbook

A practical framework for screening sites, reducing interconnection risk, and advancing projects with confidence.

Over the past decade, the biggest constraint in energy development has quietly shifted. It used to be land. **Today, it's the grid.**

Across the United States, both generation developers and large load developers face the same constraint: gaining access to the transmission system. Thousands of proposed projects are waiting for approval to connect, with more than 2,300 GW currently sitting in interconnection queues, roughly double the capacity of the existing U.S. power fleet. At the same time, demand from large loads such as data centers and industrial electrification continues to accelerate, placing additional pressure on already constrained grid infrastructure.

Only a small fraction of projects ultimately move forward. Historically, fewer than one in five generation projects that enter the queue reach commercial operation, and large load projects face similar risks when capacity is unavailable or upgrade requirements become cost-prohibitive.

For developers on both sides of the meter, this has fundamentally changed the economics of decision-making. Advancing the wrong project is no longer just inefficient; it can consume years of development time, significant capital, and critical market opportunity with no viable outcome.

In response, leading teams are shifting how projects are sourced and prioritized. Rather than starting with land or load demand and validating grid feasibility later, leading teams begin with the grid, identifying where capacity exists, narrowing to viable interconnection points, and only then committing to site control, infrastructure planning, and engineering investment.

This playbook outlines a practical framework for a grid-first approach to development.

The Core Problem: Most Projects Never Reach Construction

The development environment has changed dramatically over the past five years. Interconnection queues across North America are saturated, and the probability of project failure has increased.

Grid operators are managing unprecedented volumes of interconnection requests. In many regions, queued capacity now exceeds the amount of generation currently operating on the system. For developers, this means every queue position carries risk. Submitting the wrong project can cost years of time and significant capital.

Queue attrition is the norm. Most projects fail before reaching construction, often withdrawing due to:

- unexpected transmission upgrade costs
- congestion constraints
- competition from nearby queued projects
- extended study timelines

In response to this uncertainty, many developers adopt a volume-based strategy, submitting multiple projects in parallel with the expectation that only a few will ultimately survive. While this approach increases the likelihood of success for individual developers, it also contributes to growing queue congestion and longer study timelines across the industry.

Key Industry Reality

20%
of queued projects reach operation

70-80%
of queued projects withdraw before completion

4-6 yrs
typical study timelines

Not all project withdrawals reflect failed interconnection feasibility. Many projects withdraw due to economics, competition, permitting challenges, or shifting development priorities. However, these outcomes still reflect risk introduced when projects advance without early visibility into grid constraints.

Source: Lawrence Berkeley National Laboratory

Engineering studies remain essential to the interconnection process, but selecting the right projects for those studies has become increasingly difficult.

Formal interconnection studies rely on sophisticated power-system modeling to evaluate whether a project can safely connect to the grid. These studies determine:

- system stability impacts
- required transmission upgrades
- equipment and protection requirements
- interconnection costs

These studies are unavoidable—but initiating them for projects that ultimately prove infeasible places a significant burden on both developers and utilities. Advancing sites without early visibility into grid constraints often results in repeated engineering cycles on fundamentally constrained locations, consuming valuable engineering hours and capital.

Queue pressure alone would be manageable. But the interconnection process itself is also changing, making project outcomes less predictable and increasing the consequences of early mistakes.

By identifying non-viable sites earlier, developers and utilities benefit in two key ways:

1. **Reduced engineering rework**
   Early identification of constrained locations reduces repeated engineering cycles and minimizes investment in projects that are unlikely to succeed.

2. **Improved queue efficiency**
   Fewer non-viable projects entering detailed study helps utilities streamline workflows and prioritize resources for projects that are most likely to move forward.

The Complication: Interconnection Is No Longer Predictable

Crowded queues are only part of the challenge. The interconnection process itself is evolving, introducing new sources of uncertainty for developers.

Several structural shifts are reshaping how projects are evaluated:

- **Cluster-based studies are replacing serial reviews,** tying project outcomes to the behavior of other projects in the same group.
- **System models are becoming more dynamic,** reflecting ongoing queue activity, transmission upgrades, and changing grid conditions.
- **Higher readiness requirements,** driven in part by FERC Order No. 2023, increase the cost and commitment required to enter the queue.
- **Greater visibility into grid conditions allows earlier analysis,** but also raises expectations that projects are technically defensible before submission.

What this means:

- Interconnection feasibility is no longer a one-time check. It is a moving target that evolves as system conditions change.
- Projects that treat feasibility as a single milestone often discover constraints too late. Disciplined teams evaluate continuously, refining assumptions before committing to formal study.

> The question is no longer whether risk exists, **it is when that risk is discovered.**

The Shift to **Disciplined Development**

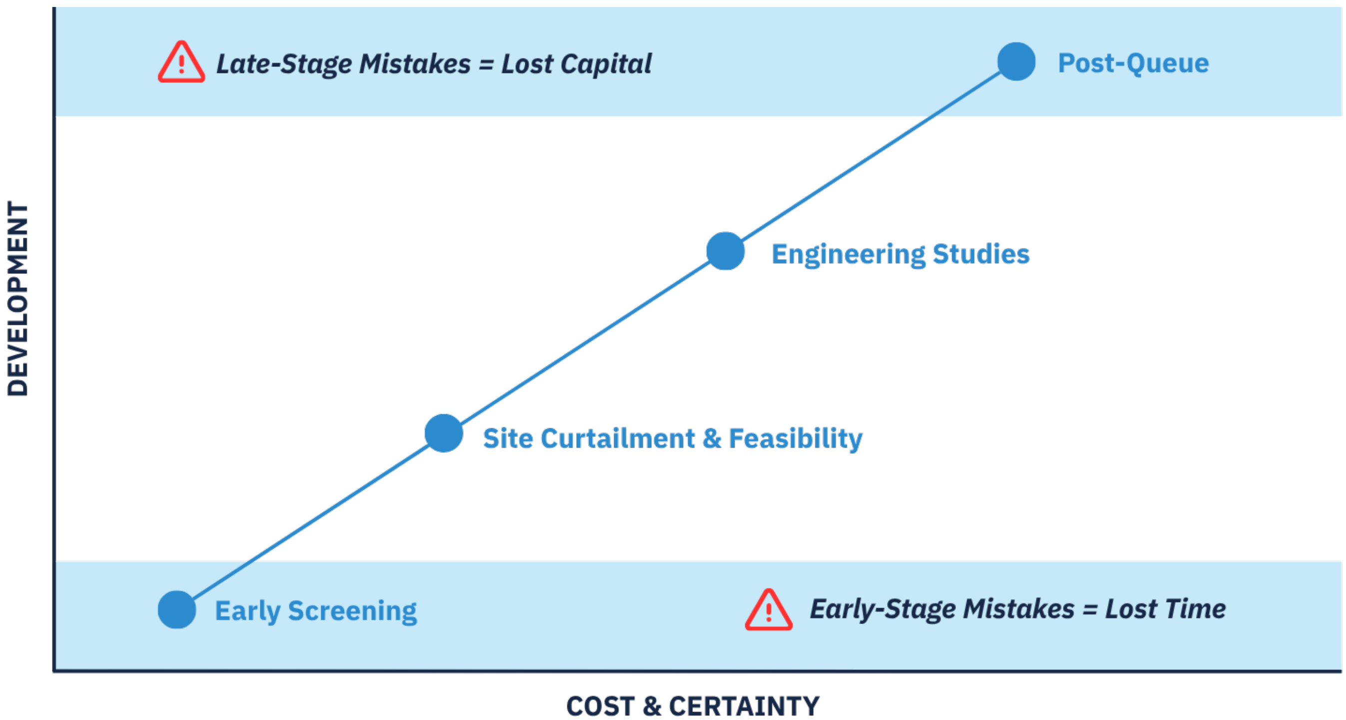
Development is shifting toward a progressive filtering model rather than a linear sequence.

Instead of advancing projects step by step, developers eliminate non-viable candidates, moving from broad market opportunities to transmission infrastructure, then to viable sites and ultimately to Points of Interconnection (POIs).

This process begins by evaluating substations and transmission lines for available capacity or the feasibility of building new facilities. Only after narrowing to promising infrastructure locations do developers commit to land and confirm specific POIs.

Each stage reduces uncertainty and focuses effort on the opportunities most likely to succeed. Executing this approach requires two capabilities working together: large-scale grid visibility and disciplined engineering validation.

Development risk profile:



Projects often fail when risks are discovered too late. The goal is to surface risks earlier, when decisions are faster and less costly.

Introducing the **Development Framework**

The framework that follows reflects how disciplined teams structure development today. While projects may begin from different starting points, they ultimately move through the same sequence of decisions required to confirm that a project can successfully interconnect.

Development does not always begin the same way. Some teams start with broad market or ISO-level screening, while others begin with a known plot of land or an existing grid connection already under evaluation. Regardless of the entry point, the objective remains the same: identify risk early, validate grid viability, and advance only the projects most likely to succeed.

1. **ISO-Specific Screening**
   Development begins within a single ISO or RTO, evaluating grid capacity across that market.
   Goal: Identify candidate POIs capable of supporting new generation.

2. **Macro Market Screening**
   Development begins with a broader regional comparison across multiple markets.
   Goal: Identify the markets most likely to support viable development.

3. **Known Plot of Land**
   Development begins with land already secured or under evaluation.
   Goal: Determine whether nearby grid infrastructure can support development.

4. **Known Grid Connection**
   Development begins near an existing or expandable interconnection point.
   Goal: Confirm that available capacity supports the proposed configuration.

> **Regardless of where a project begins, disciplined teams move through the same development stages that follow.**

Site Screening Pathway

ISO-Specific
Screen for sites within the region.

Macro-Market
Identify regions worth devleoping.

STAGE 1:
Grid Screening
Identify substations with sufficient capacity to support your target project size.

STAGE 2:
Curtailment & Market Screening
Evaluate deliverability and revenue risk using realistic power flow modeling.

STAGE 3:
Site Feasibility
Evaluate characteristics of grid-screened sites.

STAGE 4:
Project Readiness Assessment
Review if project is ready for advanced studies.

Cut hundreds of hours and thousands in wasted site studies.

Site Secured Pathway

Plot of Land
Determine feasibility of parcel.

Known Grid Connection
Significant transmission capacity already exists.

STAGE 5:
Project Validation (Shadow Study)
Validate deliverability and identify likely upgrade drivers.

STAGE 6:
Interconnection Application
Submit technical data and enter the formal study queue.

STAGE 6B: Detailed Energy Market Validation*
Stress-test revenue under realistic dispatch scenarios.

****optional***

STAGE 7: Awaiting Interconnection Approval
Advance design, permitting, and procurement to reduce construction risk.

STAGE 8:
Construction & Commission
Construct facilities and prepare for grid synchronization.

Feel more confident that your project won't fall into the 80% of projects in the interconnection queue that never reach operation.

Legend:

- **Engineering Studies**
- **Visual Grid Intelligence Platform**
- **Developer Action**
- **Able to Start at Stage 4**

The Development Framework

Stage 1:
Grid Screening

Where is capacity available to support this project?

Once candidate markets are identified, developers begin narrowing the field. The objective at this stage is to rapidly narrow thousands of potential locations to a focused set of candidate sites capable of supporting the desired megawatt scale.

This screening typically evaluates:

- available transmission capacity relative to target project size
- injection limits at substations and transmission nodes
- nearby queued projects competing for capacity
- regional congestion patterns and flow sensitivity that may limit development scale

Purpose-built grid analysis platforms make this kind of broad screening practical. Teams can screen hundreds of interconnection locations in one pass: checking injection headroom, flagging locations already saturated by competing queue activity, and identifying congestion patterns that could cap deliverability. Only then do they commit time to individual sites.

Effective grid screening depends on the quality of the underlying system model. Screening based on simplified assumptions or static capacity snapshots can produce misleading results. Early-stage evaluations should be grounded in realistic transmission models that reflect actual system topology, queued resources, and contingency behavior so that early decisions align with how the grid truly operates.

Common Failure Pattern:
Mistaking Capacity for Viability

Available injection capacity alone does not guarantee long-term project success. Without evaluating congestion, competing queue activity, and system constraints, sites that appear feasible can later face high curtailment or costly upgrades.

Projects advanced on capacity visibility alone frequently require redesign, relocation, or withdrawal once deeper modeling reveals how power actually flows through the network.

Stage 2:
Curtailment & Market Screening

Will the grid support reliable and economic operation?

With a focused portfolio of candidate sites, developers shift from broad screening to deeper evaluation of project performance under realistic grid and market conditions. The first priority at this stage is understanding **curtailment risk**, followed by evaluating potential market performance.

Curtailment risk is assessed using system capacity analysis that evaluates site performance under realistic loading and contingency conditions. This analysis helps identify locations where congestion, thermal limits, or competing injections may restrict deliverability.

Curtailment exposure is strongly influenced by how injected power flows across the transmission network. Shift factors determine how output from a specific location impacts constrained elements on the system. Locations with similar apparent capacity may experience dramatically different curtailment exposure depending on how their output distributes across constrained paths.

This stage typically evaluates:

Curtailment & Capacity Risk

- exposure to congestion-driven curtailment influenced by shift factor sensitivity
- thermal and voltage constraint drivers
- competing injections from queued and existing resources
- expected deliverability under realistic system conditions

Market Performance

- expected revenue across hourly market conditions
- generation dispatch dynamics that influence nodal congestion patterns
- congestion-driven pricing impacts
- nodal price behavior under realistic dispatch scenarios
- relative return potential across candidate sites

Why Shift Factor Matters

Two sites may appear to have similar available capacity, but experience very different curtailment exposure depending on how power flows across constrained transmission elements.

A 0.30 shift factor means 30% of a project's output flows across a constrained line. Lower shift factors generally indicate lower congestion exposure and improved deliverability under stressed system conditions.

These evaluations rely on time-series modeling that reflects system behavior across changing load, generation, and outage conditions.

Once curtailment exposure is understood, developers evaluate market performance using time-series simulations that capture realistic system behavior across changing conditions.

Together, these analyses identify which locations combine manageable curtailment exposure with strong revenue potential, highlighting the sites most likely to deliver durable economic performance before advancing to formal engineering studies.

By the end of this stage, developers should understand not just where capacity exists, but how the grid behaves under real operating conditions.

Field Example: Curtailment Risk Eliminated Early

A developer screened several substations with enough injection capacity for a 200 MW solar project. Each looked viable. Curtailment analysis combining capacity modeling with energy market simulations showed power flows concentrating on constrained paths, resulting in projected curtailment over 25%.

Although the sites met basic capacity requirements, the deliverability risk made long-term performance uncertain. By eliminating these locations early, the team avoided unnecessary engineering effort and redirected focus to stronger candidates.

Stage 3:
Site Feasibility

Are site and infrastructure conditions feasible?

After promising interconnection points are identified, developers shift focus from the grid to the land itself. The objective at this stage is to confirm that a site can physically support the proposed project while aligning with the infrastructure assumptions established in earlier stages.

Even sites with strong grid potential can be eliminated at this stage if land or environmental constraints introduce unacceptable risk or cost.

Development teams typically evaluate:

- parcel size, configuration, and usable acreage
- environmental and permitting constraints
- topography, grading, and constructability requirements
- proximity to substations or transmission corridors
- land ownership structure and leasing feasibility
- access to roads and supporting infrastructure

At this stage, many candidate locations are removed from consideration as physical realities are tested against project assumptions. The remaining sites represent locations that align both grid feasibility and physical constructability.

Common Failure Pattern:
Grid-Viable Sites That Cannot Be Built

Even when grid capacity appears favorable, site-level constraints can prevent successful development. Environmental restrictions, grading challenges, permitting limitations, or infrastructure access issues may introduce costs or delays that were not apparent during early screening.

Projects that advance without validating site constructability often require redesign or abandonment after significant engineering effort has already been invested.

Stage 4:
Project Readiness Assessment

Is this project ready to advance?

Before committing to advanced engineering studies or entering formal interconnection queues, disciplined development teams conduct a readiness review to confirm that a project has cleared the major sources of early-stage risk and is positioned to justify deeper engineering investment.

This assessment brings together findings from grid screening, system performance analysis, and site due diligence to determine whether the project is truly ready to advance into detailed study. In many cases, developers supplement internal evaluation with an independent engineering perspective to pressure-test assumptions before committing significant capital.

Key questions evaluated at this stage include:

- Is the selected POI realistic for the proposed project size and operating profile?
- Are there identifiable grid constraints that could introduce significant upgrade risk or delay?
- Does the site demonstrate manageable curtailment exposure and credible revenue potential?
- Are land, permitting, and infrastructure requirements aligned with project timelines?
- Is the project likely to withstand formal interconnection study review?

This readiness review prioritizes capital and engineering investment toward projects with the highest probability of success, ensuring that advanced studies are reserved for locations that have already demonstrated strong technical, physical, and economic alignment.

Why Capital Discipline Matters Early

While this framework is designed to improve technical decision-making, its greatest impact is often financial.

Most development portfolios begin with dozens or even hundreds of potential opportunities. Only a small fraction will ultimately justify the capital required to reach construction. The ability to eliminate weak candidates early allows development teams to concentrate time, engineering effort, and financial resources on projects with the highest probability of success.

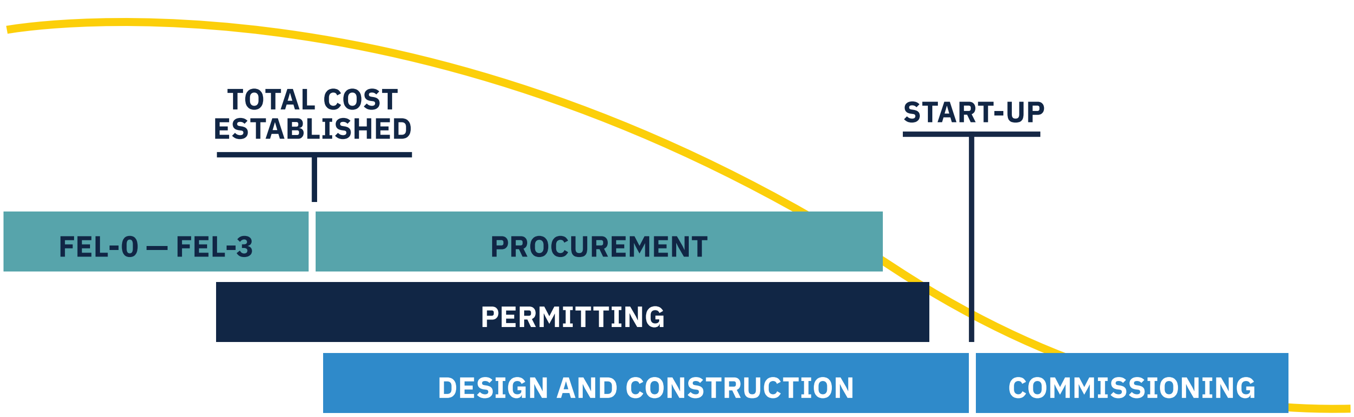
This discipline becomes increasingly important when working with capital partners. Investors and lenders expect projects entering formal study and financing phases to be supported by defensible technical assumptions and credible economic performance.

Teams that apply structured filtering early are better positioned to:

- prioritize capital toward the strongest opportunities
- reduce exposure to stranded development costs
- maintain confidence with lenders and equity partners
- accelerate the transition from development to construction

In competitive interconnection environments, capital discipline is often as important as technical accuracy.

Ability to Influence Project Cost



Early project planning is where cost control happens. The ability to influence project outcomes is highest during the front-end loading (FEL)-0 through FEL-3 phases—and as a project advances through its lifecycle, that window narrows.

Two Paths to Interconnection Insight

At this point in the development lifecycle, teams typically follow one of two paths:

1

Proactive Validation (Shadow Study)

Some developers conduct engineer-led shadow studies that mirror formal interconnection modeling. This approach provides earlier visibility into technical risks and allows teams to refine projects before entering the queue.

Move to Stage 5

2

Formal Queue Submission

Other developers proceed directly into the utility or ISO study process and wait for official results before making further decisions. While required for project advancement, this path introduces longer timelines and limits the ability to adjust early-stage assumptions.

Skip to Stage 6

Understanding the tradeoffs between these approaches is **essential to disciplined project development.**

Stage 5:
Proactive Validation (Shadow Study)

What will the interconnection study reveal before entering the queue?

Before submitting to the queue, some teams run a shadow study to evaluate how their project will likely perform under the same conditions utilities and ISOs use. Others go straight to the queue submission and wait for official results. Both paths eventually reach the same engineering scrutiny. The difference is when it happens and what it costs to respond.

The objective at this stage is to replicate the type of engineering analysis that will eventually be performed by the interconnection authority, providing early visibility into risks and hidden costs that could otherwise surface months or years later.

Shadow studies mirror the structure of formal interconnection evaluations, allowing developers to identify technical constraints, upgrade exposure, and deliverability risks before committing to a queue position.

This stage typically evaluates:

- expected thermal and voltage constraint exposure
- potential transmission upgrade requirements
- deliverability limitations under contingency conditions
- sensitivity to competing queued projects
- alignment between project assumptions and grid realities

Shadow studies apply engineering-grade methods that closely resemble formal interconnection modeling. The goal is not to replace the official study process, but to anticipate its outcomes and reduce uncertainty before entering the queue.

For disciplined development teams, this stage represents a critical risk-control point, allowing projects to be refined, resized, relocated, or deferred before significant time and capital are committed.

Field Example: Shadow Study Prevented Costly Queue Entry

A developer preparing to enter the interconnection queue conducted a shadow study to evaluate a proposed project configuration. The analysis identified a potential thermal overload on a nearby transmission line under contingency conditions, triggering a likely upgrade requirement.

Rather than entering the queue with an unmodified design, the development team resized the project and shifted the interconnection point slightly upstream. The revised configuration reduced upgrade exposure and allowed the project to proceed with improved cost certainty.

Stage 6:
Interconnection Application

*REQUIRED

Have we submitted a defensible project to the queue?

After completing early-stage screening and readiness validation, developers formally enter the interconnection process by preparing and submitting an application to the applicable ISO or utility.

This stage converts project assumptions into a technically defensible submission that defines how the project will connect to the grid. Submitting an interconnection request is not administrative, it is a technical commitment. Errors, omissions, or unrealistic assumptions can introduce delays, increase study costs, or require resubmittal.

This stage typically includes:

- defining the proposed POI and project configuration
- confirming project size, technology type, and operating characteristics
- preparing required technical documentation and modeling inputs
- validating electrical parameters and equipment assumptions
- coordinating land, permitting, and development readiness
- assembling required forms, deposits, and submission materials

Because these inputs establish the assumptions used throughout formal study, many developers rely on experienced engineering consultants to prepare or review submissions. Strong submissions reduce rework and position projects for more efficient progression through formal study phases.

At this point, the project transitions from internal evaluation to formal system review, where timelines are governed by utility and ISO processes.

Common Failure Pattern: Entering the Queue with Unrealistic Project Assumptions

Applications built on incomplete or unrealistic assumptions introduce avoidable risk. Incorrect equipment data or missing inputs often lead to delays, redesign, or resubmittal.

Projects grounded in validated assumptions move through formal study faster, with fewer revisions and greater confidence in outcomes.

Stage 6B:

Detailed Market Validation & Portfolio Prioritization

***HIGHLY RECOMMENDED**

Which projects justify the deepest investment, and will they hold up under real financial scrutiny?

While the interconnection application is under review, developers often perform deeper economic validation to confirm that the project remains financially competitive under realistic long-term market conditions.

Earlier in the development process, high-level operational screening (Stage 2) helps identify promising locations by evaluating curtailment exposure and relative revenue potential across multiple candidate sites. However, once a project is selected and formally submitted, developers often perform a more detailed market analysis focused on the specific configuration of the final project.

The objective at this stage is to confirm that the selected project remains economically viable and attractive to lenders, investors, and strategic partners.

This detailed analysis typically evaluates:

- expected energy market revenues under long-term hourly market simulations
- locational marginal pricing (LMP) behavior at the selected POI
- congestion, curtailment, and basis risk exposure
- long-term market dynamics and competitive resource growth
- sensitivity to regulatory or market design changes
- financial model performance, including projected IRR and cash flow stability

Unlike earlier screening-level analysis, this stage applies project-specific assumptions—including final sizing, configuration, and operating strategy, to validate investment readiness.

This level of economic validation is often required to support financing discussions and demonstrate that the project is bankable under realistic operating conditions.

Stage 7:
Awaiting Interconnection Approval

What actions can be taken now to reduce construction risk once approval is received?

After submitting an interconnection application, projects enter the formal study and review process. During this period, the ISO or utility evaluates system impacts, identifies required upgrades, and determines whether the project can proceed under defined technical conditions.

While developers await final interconnection approval, this period is operationally critical. Disciplined teams use this time to prepare for execution so that construction can begin quickly once approval is granted.

The objective at this stage is to reduce downstream schedule risk by aligning equipment procurement, financing, and construction planning with expected interconnection outcomes.

Key activities during this stage typically include:

- reviewing preliminary study results and refining project assumptions
- securing major equipment with long manufacturing lead times
- negotiating supplier agreements for critical components
- advancing financing discussions with lenders and investors
- refining project schedules and construction sequencing
- coordinating permitting and environmental approvals
- evaluating strategic options if project risks change

Long-lead equipment, such as transformers, breakers, and major electrical components, often requires **60 to 80 weeks or more** for delivery. Ordering equipment early, based on credible project assumptions, helps ensure that construction timelines remain achievable once approval is granted.

At this stage, developers may also reassess project positioning within the interconnection queue. In some cases, queue positions represent transferable value, and developers may choose to sell or transfer a project rather than construct it directly.

This waiting period gives developers an opportunity to get additional insights from experienced engineering consultants. These specialized advisors help interpret evolving study results, refine technical assumptions, coordinate equipment specifications, and ensure that procurement decisions align with expected interconnection requirements.

Projects that use this waiting period strategically are often positioned to move into construction significantly faster than those that delay execution planning until final approval is received.

Field Example: Early Equipment Procurement Reduced Schedule Risk

While awaiting approval, a developer secured manufacturing capacity for a critical transformer identified in preliminary studies.

When the interconnection agreement was executed, equipment delivery aligned with construction schedules, reducing delay risk and enabling faster project execution.

Stage 8:
Construction & Commissioning

Is the project being built and commissioned correctly?

Once interconnection approval is granted and an agreement is executed, the project moves into full construction and commissioning. At this stage, earlier decisions are translated into physical infrastructure, and timelines depend heavily on execution discipline.

The objective is to build the facility according to approved engineering plans, complete required testing, and safely connect to the transmission system.

Key activities during this stage typically include:

- constructing electrical and physical infrastructure
- installing generation or load equipment
- completing substation and interconnection facilities
- coordinating with utilities for system integration
- performing testing and commissioning procedures
- verifying compliance with utility and ISO requirements
- achieving final grid synchronization

Commissioning is a critical milestone that validates system performance, confirms protection functionality, and ensures compatibility with grid requirements before commercial operation begins.

Developers and utilities have significant resources dedicated to construction and commissioning. Engineering consultants provide additional support during this phase, helping resolve technical issues, coordinate testing, support inspections, and reduce delays caused by installation or design discrepancies.

Successful execution results in a fully operational project capable of safely delivering power or supporting load under approved interconnection conditions.

Key Takeaway & Closing

Energy development is no longer a linear process; it is a disciplined filtering exercise.

Developers may begin with thousands of potential locations, but only a small number will survive the technical, economic, and execution hurdles required to reach construction and operation.

A structured development framework enables teams to:

- eliminate non-viable sites before major capital is committed
- focus engineering and financial resources on the strongest candidates
- submit defensible projects into interconnection queues
- position approved projects for faster, more efficient construction

In an environment where interconnection timelines stretch into years and equipment lead times extend even longer, early discipline determines downstream success. Projects that survive to construction are rarely accidental—they are the result of deliberate filtering at every stage.

Transmission access has become the **defining constraint in modern energy development.**

As demand for both generation and large-load infrastructure accelerates, success will increasingly depend on the ability to identify projects that withstand technical scrutiny, economic pressure, and execution risk.

Developers that combine grid intelligence, disciplined screening, and targeted engineering validation will be best positioned to advance projects through increasingly competitive interconnection environments.

The future of energy development will not be defined by who identifies the most sites. It will be defined by who advances the projects that can connect, be financed, and be built.

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