



A Sequential Gate Framework for Pre-Financial-Close Attrition in United States Utility-Scale Solar and Battery Storage Project Finance

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Abstract

Purpose: Most utility-scale solar and battery storage capacity proposed in the United States is never built, and much of the loss occurs after a project has a site, an interconnection position and a revenue case but before financial close. This paper asks which gates in that interval account for the attrition, how they interact, and how the risk differs between contracted solar and standalone storage.

Design: A critical review with framework synthesis covered 252

sources: peer-reviewed energy economics, finance and engineering research, the statutory and regulatory record through September 2025, queue data and the applied procurement and risk governance literature, coded by enforcing counterparty and detection point.

Findings: Six sequential gates emerge. A survival model, a debt-sizing identity and an expected-loss expression formalise their interaction, and a hypothetical portfolio of 70 solar and 30 storage projects gives a complete worked calculation with low, base and high pass probabilities, a Monte Carlo interval, correlated-risk scenarios and a comparison with a parallel-gate model. Under the assumed ranges 25 to 43 of 100 projects reach close; a cluster-study delay that also defeats the tax credit deadline is the most damaging correlated scenario.

Originality: To the authors' knowledge no prior study treats the interval as one conditional decision process whose gates are enforced by identifiable counterparties under identifiable instruments; the probabilities are assumptions to be estimated, not observed outcomes.

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1. Introduction

1.1. The Problem and Its Setting

The United States added more utility-scale solar and battery storage capacity between 2022 and 2025 than in any earlier period, yet most proposed capacity is never built. Lawrence Berkeley National Laboratory reports that, of projects that requested interconnection between 2000 and 2019, only 13 percent had reached commercial operation and 77 percent had been withdrawn, and that the active queue at the end of 2024 still held 956 GW of solar and 890 GW of storage ^[1]. A withdrawal is the visible symptom of a failure that usually happened elsewhere: an unbankable revenue case, an unqualified tax credit, a cost estimate above the debt the project could carry, or a permit contested long enough for the position to lapse. The interval between holding site control, an interconnection position and a revenue case and the moment at which lenders, tax equity investors and credit buyers fund the project is where most of the capital at risk in United States clean energy development is lost.

Three features of the institutional setting matter. First, project finance is the dominant structure because contracted or hedged cash flows can be ring-fenced in a special purpose entity with limited recourse^[2-4], which concentrates the credit decision at close, where lender, tax equity investor or credit buyer and sponsor fund simultaneously and conditionally; project finance carries most large renewable projects in Germany^[2], and United States developers without an investment-grade balance sheet have no alternative^[5]. Second, tax-motivated equity is distinctive: because the sections 48/48E and 45/45Y credits can only be used by a taxpayer with sufficient liability, developers have relied on partnership-flip and sale-leaseback structures with tax equity investors, mostly large banks^[6], and since 2022 on credit sales under section 6418, a market that grew rapidly in 2023 and 2024^[7, 8]; the credit is only worth what the facility can qualify for, which makes the tax credit gate a credit gate in its own right^[9]. Third, the policy environment changed four times between August 2022 and August 2025: the Inflation Reduction Act, Order No. 2023 and its rehearing order, the Commerce determinations of April 21, 2025, and Public Law 119-21, Executive Order 14315 and Notice 2025-42^[7, 10-14]; Section 3.1 sets this sequence out first because every gate is defined against it.

The cost of capital for these projects has fallen as lenders have gained experience, policy has reduced revenue risk and equipment has become cheaper^[15-19]; state portfolio standards and federal credits drove the first decade of deployment^[20, 21] and cost has since replaced mandates as the driver^[22]. The cost of debt of renewable firms is not higher than that of other firms once firm characteristics are controlled for^[23], loan-specific mitigation rather than borrower tax position drives corporate debt pricing^[24], and guaranteed debt changes the risk choices a sponsor makes^[25]. The obstacle at close is therefore rarely the price of capital but the conditions precedent that make capital available at all, which counterparties enforce through scenario-based financial modelling^[26], capital allocation rules^[27], risk-based internal control^[28, 29], compliance-driven risk governance^[30, 31] and the data management on which forecasting rests^[32, 33]; the corporate financial analytics literature describes these disciplines in general^[34-37] and the project finance literature applies them to a single-asset borrower^[38-40].

1.2. Prior Literature and The Gap

Four bodies of work bear on the interval, and none treats it whole. The finance literature documents the cost of capital of renewable projects, the conditions under which private capital is mobilised and the de-risking role of public finance institutions^[2, 15, 16, 41-45], but its unit of analysis is the financed project or firm, so projects that never reach funding are absent by construction. The engineering and economics literature documents interconnection constraints, curtailment and the declining market value of solar^[46-52], explaining why a position can be technically but not commercially deliverable, but stops at the queue. Project management scholarship examines cost overruns^[53, 54], the governance of multinational infrastructure delivery^[55-57] and scheduling and resource disciplines^[58-60], but its evidence comes from projects that were built, so it measures drift after close rather than attrition before it. The applied literature on procurement, risk governance and financial analytics^[27, 28, 61-63] describes the controls counterparties apply, but without reference to the statutes and orders that give those controls their content in

this asset class.

What is missing is a treatment of the development-to-close interval as a single decision process in which the gates are sequential, the pass probabilities are conditional on one another, and the controls applied at each gate are set by identifiable counterparties under identifiable statutes and orders. The practitioner literature knows the interval intimately but writes about it in term sheets and closing checklists rather than in testable form^[8, 12]; the de-risking literature comes closest in asking which policy instruments move private capital^[41, 42], but does not specify where in the sequence each instrument acts or how a change in one propagates through the others. The 2025 changes to the tax credit regime make that propagation the central question for every wind and solar project in the queue, because a deadline on one gate alters the value of every position held at the others^[12, 14].

1.3. Research Questions and Contribution

This paper fills the gap with a critical review and a conceptual framework organised around three research questions. RQ1: which gates between development and financial close account for attrition, and by what mechanism does each fail? RQ2: how do the gates interact in a survival and debt-sizing model, and which dominate close probability under the statutory window from July 4, 2025 to December 31, 2027? RQ3: how does the risk profile differ between contracted utility-scale solar and standalone merchant storage? Three contributions follow. First, the paper gives a gate-by-gate taxonomy of failure modes that links each mode to the counterparty that enforces it and the evidence on its frequency (Table 5). Second, it formalises the interval as a survival model with a debt-sizing identity and an expected-loss expression (Equations 1 to 6), works the model through a hypothetical 100-project portfolio with uncertainty intervals and correlated scenarios (Tables @7 to @9), and compares it with a parallel-gate alternative (Equations 7 and 8, Table 10). Third, it contrasts solar with standalone storage, whose revenue stack, degradation profile and credit treatment differ enough that the same framework produces a different ordering of gates (Table 11). The originality claim is bounded: stage-gate governance of capital projects^[55, 56], staged-investment and real-options treatments of energy assets^[64] and the de-risking literature^[41] each contain part of the structure, and survival analysis is an established tool; to the authors' knowledge no prior study joins them for this interval with the enforcing counterparty and governing instrument named at every gate, and that is the sense in which the framework is new. The argument draws on the literature on financial risk governance, procurement analytics and capital allocation because the controls applied at close are general risk-management practice applied to one asset class^[27, 28, 30]. Section 2 sets out the methods, Section 3 the results (regulatory sequence, six gates, framework, sensitivity, the worked portfolio and the solar-storage comparison), Section 4 the discussion, limitations and research agenda, and Section 5 concludes.

2. Materials and Methods

2.1. Research Design

The study is a critical review with framework synthesis rather than a systematic review, because the interval is governed by instruments (statutes, orders, notices, term sheets) and practices (diligence, credit approval, capital allocation)

documented in heterogeneous sources that rarely report comparable quantitative outcomes, so there is nothing to aggregate; a critical review reads the sources against a question and builds a structure that explains them ^[65, 66], and framework synthesis maps the mechanisms onto a prior structure, here the closing sequence of a project finance transaction, revising it where the evidence does not fit ^[55, 67]. The paradigm is positivist: the gates are treated as real features of the transaction process whose pass probabilities could be estimated from project data, and the propositions are specified to be falsifiable by such data ^[26, 27]. The first author's working knowledge of closing practice structured the gates and selected the controls, not the evidence; every empirical claim in Section 3 is attributed to a published source.

2.2. Search Strategy and Sources

Four evidence streams were searched. The first is peer-reviewed research in energy economics, energy policy, finance and operations research, identified through Crossref searches restricted to journal articles with search strings built from project finance, power purchase agreement, interconnection queue, investment tax credit, tax equity, debt service coverage, debt sizing, cost overrun, curtailment, market value of solar, battery storage revenue and social acceptance, each combined with renewable, solar, wind or storage, with a window ending September 30, 2025, supplemented by citation chaining from the Lawrence Berkeley and National Renewable Energy Laboratory report series ^[1, 46, 68]. The second is the primary legal record (the Inflation Reduction Act, Public Law 119-21, Executive Order 14315, Notice 2025-42, Orders No. 2023 and 2023-A and the Commerce determinations of April 21, 2025), each read in original form and cross-checked against two practitioner summaries ^[8, 12]. The third is the applied literature on

procurement, contract governance, project management, financial analytics and risk governance in energy and infrastructure, drawn from a consolidated reference set covering EPC risk ^[61, 62, 69], project governance ^[55, 67, 70], due diligence and risk analytics ^[63, 71, 72], compliance and contract review ^[73-75] and energy transition analytics ^[76-78]. The fourth is the laboratory and agency report series on queue composition, cost and pricing ^[1, 68, 79]. Journal articles, handbook chapters, statutes, orders, notices, laboratory reports and law-firm summaries of enacted instruments were admitted; preprints, conference abstracts and encyclopaedia entries were excluded.

2.3. Screening and Corpus

A source was retained if it addressed a mechanism by which a project with an interconnection position, site control and a revenue case could still fail to reach funding, supplied evidence on the frequency or magnitude of such a mechanism in the United States or a comparable market, or described a control that a lender, tax equity investor, credit buyer or independent engineer applies at close. Sources on operating-phase performance ^[80-82], distributed solar and microgrids below 1 MW ^[83-85] and markets without a tax credit ^[86-88] were retained only where the mechanism transfers to the utility-scale United States case ^[66, 89, 90]. Screening had two stages: 185 candidate peer-reviewed and primary sources from the searches and citation chaining were screened on title and abstract and verified against Crossref or the issuing agency, leaving 106 verified sources of which 101 are cited; in parallel, 296 candidate items from the applied consolidated reference set were screened on title and subject area against the three inclusion rules, which reduced them to 161 relevant items, of which 151 are cited. The included corpus therefore comprises 252 sources. Table 1 reports its composition by stream and the role each stream plays in the framework.

Table 1: Composition of the reviewed corpus by evidence stream, with the number of included sources and the role each stream plays in the framework.

Evidence stream	Included sources	Representative sources	Role in the framework
Peer-reviewed energy economics, finance, engineering and market analysis	90	[15], [16], [2], [23], [40], [38], [46], [47], [48], [49], [91], [92]	Cost of capital, debt sizing, risk pricing; interconnection, curtailment, revenue value of solar and storage
Primary legal and regulatory record	8	[7], [93], [13], [14], [10], [94], [11]	Gate definitions, deadlines and thresholds
Practitioner summaries of enacted instruments	2	[8], [12]	Cross-check of statutory thresholds and dates
Laboratory and agency reports	1	[1]	Frequency of withdrawal, queue composition, time to commercial operation
Applied procurement, project governance, construction risk and contract literature	67	[61], [62], [55], [73], [74], [59]	Controls applied by EPC counterparties, lenders and counsel
Applied financial analytics, audit and risk governance literature	46	[63], [27], [28], [30], [26], [37]	Diligence, scenario modelling, capital allocation discipline
Energy transition, regulatory compliance and community acceptance analytics	38	[76], [77], [95], [96], [97], [78]	Permitting and social acceptance gate; compliance record examined at close
Total	252		

2.4. Data Extraction and Coding

From each included source four items were extracted: the failure mechanism or control it described, the counterparty that detects or enforces it, the point in the closing sequence at which detection occurs, and any quantitative evidence on frequency, magnitude or timing. The coding scheme for the counterparty had seven values (transmission provider or FERC; offtaker; tax counsel, credit buyer or IRS; lender,

independent engineer or model auditor; sponsor investment committee; permitting authority, court or insurer; other), and the scheme for the detection point followed the sequence of a conventional closing checklist from interconnection agreement to funding ^[40, 63]. Evidence was weighed by proximity to the United States utility-scale case and by whether the source reported project-level data: the Lawrence Berkeley queue data anchor frequency ^[1], the Sovacool

datasets anchor construction cost drift [53, 54], and cross-country and firm-level studies establish mechanisms rather than magnitudes [23, 65]. Where sources disagreed on a threshold or date the primary instrument governed; where they disagreed on a mechanism both readings were recorded (Section 4.2). Mechanisms detected by the same counterparty at the same point were grouped into a gate, and a gate was retained only if at least two independent streams supplied evidence for it [28, 30].

2.5. Framework Derivation and Model Specification

The six gates that emerged from coding were ordered by the sequence in which their outputs become conditions precedent to funding, and the survival model in Section 3.8 treats them as sequential with conditional pass probabilities. The multiplicative form follows from close requiring every condition precedent to be satisfied, and conditioning replaces a correlation structure because a developer has coarse information about each gate and none about their joint distribution [26, 27]. The debt-sizing identity in Section 3.9 is the standard sculpted-debt formulation of project finance lending, in which debt service is set to a target coverage ratio against cash flow available for debt service in a downside case [38-40], and the tax credit value expression follows the statutory rate structure of sections 48E and 6418 [7, 12]. The expected development-loss expression in Section 3.10 is a staged-investment expectation of the kind used in capital allocation under uncertainty [27, 98]. Numerical values are assumptions, not estimates from a project dataset. Each gate carries a low, base and high pass probability (Table 6); the base values are chosen so that the implied end-to-end rate reconciles with the queue completion rate reported by the Lawrence Berkeley National Laboratory [1] once two further assumptions are made explicit (Section 3.8), and the ranges reflect the direction of the 2025 statutory changes [12, 14]. The model is worked through a hypothetical portfolio of 70 contracted solar and 30 standalone storage projects (Section 3.12). Uncertainty is propagated by Monte Carlo simulation with 10,000 draws in which each pass probability follows a triangular distribution on its low, base and high values and the number of projects reaching close is drawn binomially; dependence between the interconnection, tax credit and sponsor capital gates is introduced through a Gaussian copula with a common factor and pairwise correlation of 0.3 or 0.6 [26, 27]. A parallel-gate alternative, in which all gates are resolved simultaneously and the project fails if any gate fails, is specified in Equations (7) and (8) and compared with the sequential model on close probability and expected development loss. The sensitivity design varies each gate's pass probability from 0.5 to 1.0 with the others at base case, and the band around the steepest curve shows the 5th to 95th percentile of the other gates' product under the triangular draws. All numbers in Tables @7 to @10 and Figures 2 and 3 are produced by one script with a fixed random seed, and the parameter tables contain every input, so the calculation can be repeated by hand or re-run with a different parameter

set; figures were generated with matplotlib at 600 dots per inch.

2.6. Quality and Validity

Three measures address the validity of a review whose evidence is heterogeneous. Triangulation across streams was required for every gate: a gate enters the taxonomy only where a peer-reviewed source, a primary instrument or laboratory dataset, and an applied control source each describe it, so that no gate rests on a single type of evidence [1, 61, 65]. Statutory thresholds and dates were verified against the primary instrument and two practitioner summaries by different firms [8, 12], the instrument governing any difference. Every equation is in closed form and every parameter is in Tables 6 and 10, so all results can be recomputed. The method's limitations (Section 4.5) are that the pass probabilities are assumed, the sequential structure simplifies gates worked in parallel, and the queue data record withdrawal rather than cause [1, 66]; they bound the inferences in Section 4 but not the identification of the gates, which rests on the convergence of the three streams [28, 40].

3. Results

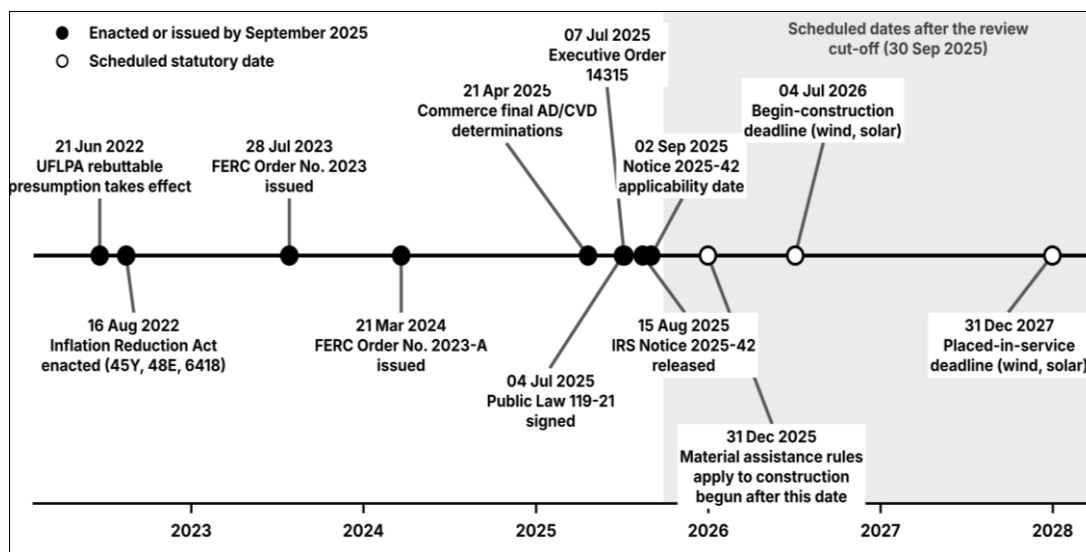
3.1. The Statutory and Regulatory Sequence Governing the Interval

The first result is the sequence of instruments against which every gate is defined, because the coding in Section 2.4 showed that the content of each control at close is set by an identifiable statute, order or notice. The Inflation Reduction Act of 2022, signed on August 16, 2022, restructured the credits into the technology-neutral sections 45Y and 48E, added the energy community and domestic content bonuses and introduced transferability [7]. FERC Order No. 2023 of July 28, 2023 and Order No. 2023-A of March 21, 2024 replaced serial studies with cluster studies and imposed readiness deposits and withdrawal penalties to clear speculative projects from the queue [10, 94]. The Department of Commerce's final antidumping and countervailing duty determinations of April 21, 2025 on crystalline silicon photovoltaic cells from Cambodia, Malaysia, Thailand and Vietnam raised the cost and reduced the certainty of module supply for projects without secured inventory [11].

The fourth change was the largest: Public Law 119-21 of July 4, 2025 terminates the 45Y and 48E credits for wind and solar facilities placed in service after December 31, 2027 unless construction began by July 4, 2026, excepts storage, and adds prohibited foreign entity, material assistance and accelerated domestic content conditions [12, 93]; Executive Order 14315 of July 7, 2025 directed strict enforcement [13]; and Notice 2025-42 of August 15, 2025 removed the five percent safe harbour for wind and solar above 1.5 MW AC and made physical work the sole beginning-of-construction test from September 2, 2025 [8, 14]. Table 2 sets the milestones out in sequence with the gate each acts on; Figure 1 places them on a timeline and distinguishes enacted from scheduled dates.

Table 2: Statutory, regulatory and administrative milestones governing the development-to-close interval, 2022 to 2027.

Date	Instrument	Effect on the closing gates
June 21, 2022	Uyghur Forced Labor Prevention Act rebuttable presumption takes effect	Module shipments detained pending supply chain tracing; delivery dates and EPC schedules at risk (credit gate)
August 16, 2022	Inflation Reduction Act of 2022, Pub. L. 117-169	Sections 45Y and 48E, energy community and domestic content adders, section 6418 transferability (tax credit gate)
July 28, 2023	FERC Order No. 2023	Cluster studies, readiness deposits, site control requirements, withdrawal penalties (interconnection gate)
March 21, 2024	FERC Order No. 2023-A	Rehearing order clarifying Order No. 2023 obligations (interconnection gate)
April 21, 2025	Commerce final AD/CVD determinations, cells from Cambodia, Malaysia, Thailand, Vietnam	Module cost and supply certainty reduced for uncontracted projects; ITC injury deadline June 2, 2025 (credit gate)
July 4, 2025	Public Law 119-21	Wind and solar 45Y/48E credits terminate for facilities placed in service after December 31, 2027 unless construction begins by July 4, 2026; prohibited foreign entity and material assistance rules; accelerated domestic content thresholds (tax credit gate)
July 7, 2025	Executive Order 14315	Treasury directed to enforce termination strictly and restrict safe harbours (tax credit gate)
August 15, 2025	IRS Notice 2025-42	Five percent safe harbour removed above 1.5 MW AC; physical work test sole method; four-year continuity safe harbour; applies to construction beginning on or after September 2, 2025 (tax credit gate)
December 31, 2025	Material assistance rules apply to 45Y/48E facilities beginning construction after this date	Supply chain composition becomes a credit-qualification condition (tax credit and credit gates)
July 4, 2026	Begin-construction deadline for wind and solar	Projects beginning construction after this date must be placed in service by December 31, 2027 (tax credit gate)
December 31, 2027	Placed-in-service deadline for wind and solar not safe-harboured	Final date for credit eligibility of late-starting projects (tax credit gate)

**Fig 1:** Timeline of the statutory, regulatory and administrative milestones that govern the development-to-close interval for United States wind, solar and storage projects, 2022 to 2027; open markers are statutory dates scheduled after the review cut-off of September 2025.

The consequence for the interval is that the tax credit gate, which under the Inflation Reduction Act had become easier to pass, became in 2025 the gate with the hardest deadline. A wind or solar project that cannot demonstrate physical work before July 5, 2026 must be placed in service by the end of 2027 to earn any credit, and a project that begins construction in time but sources equipment from a prohibited foreign entity above the material assistance threshold loses the credit regardless^[8, 12]. The interconnection gate, meanwhile, became more expensive to hold but faster to pass under Order No. 2023's cluster process^[10, 99]. These two gates now

interact: an interconnection position maturing in 2028 is worth much less to a solar project than before July 2025, and its holder must decide whether to spend development capital on a project whose tax credit case has closed^[27, 100].

3.2. Gate One: Interconnection

The interconnection gate is passed when a project holds an executed interconnection agreement with network upgrade costs that the financial model can absorb and a scheduled in-service date that precedes the revenue and tax credit deadlines. The literature documents three ways this gate fails.

The first is study duration: median time from interconnection request to commercial operation rose from under two years for projects built between 2000 and 2007 to more than four years for projects built between 2018 and 2024 ^[1], and a developer who entered a queue expecting a 2026 in-service date may find the cluster study delivering a 2028 date that no offtaker or credit buyer will underwrite ^[99, 101]. The second is the network upgrade allocation. Under the serial study regime, late-stage projects were assigned upgrade costs that reflected the withdrawal of earlier projects, and the restudy cascade was itself a source of withdrawal ^[10, 79]. Order No. 2023 replaced serial studies with clusters, allocated upgrade costs proportionally within a cluster and imposed withdrawal penalties and readiness deposits, which raises the cost of holding a speculative position and shifts failure earlier in the sequence ^[10, 94]. The third failure is locational: transmission congestion and curtailment reduce the energy value of solar in high-penetration regions so that a position that is technically deliverable is not commercially deliverable ^[47-49].

The evidence on how often this gate is the proximate cause

of failure is incomplete because queue data record withdrawal, not reason, and because the queue statistics measure a different interval from the one studied here. The 13 percent completion rate for the 2000 to 2019 cohort ^[1] is the share of interconnection requests that reached commercial operation; it is not a probability of financial close, since it counts attrition before a project has a site, a revenue case and a studied position (the point at which this paper's interval begins) and attrition during construction after close. The 77 percent withdrawal rate ^[1] likewise overstates the interconnection gate's share because many withdrawals are projects that failed a later gate and surrendered their position, and the 12 percent fall in active queue volume in 2024 reflects both Order No. 2023 withdrawals and sponsor-level portfolio pruning ^[1, 102]. Table 3 sets out which queue events can and cannot be assigned to a gate; the reader should see in it that only the first two rows are observable in the published queue data and that every later row is inferred. The framework therefore uses the queue statistics only as a calibration anchor and a bound (Section 3.8), not as an estimate of any gate's pass probability.

Table 3: Observable interconnection-queue events and the closing gate to which each can be assigned.

Queue event recorded by the transmission provider	Observable in published queue data	Gate to which the event can be assigned	Basis for the assignment
Withdrawal before the cluster study report or readiness deposit	Yes, by date and stage ^[1]	Gate 1 in part; also pre-interval screening	Readiness deposits and penalties under Order No. 2023 force the decision here ^[10, 94]
Withdrawal after the study report but before an executed agreement	Yes, by date and stage ^[1]	Gate 1 if upgrade cost or in-service date; gate 2 or 3 if deliverable but unsaleable	Reason not recorded; needs sponsor or offtaker records ^[10, 101]
Withdrawal after an executed agreement	Yes, as a count; reason not recorded ^[1]	Any of gates 2 to 6	Inferred only; surrendered for a reason outside the queue
Suspension or in-service date extension	Partly, where the provider reports it	Gate 3 (deadline interaction) or gate 5	Extensions beyond December 31, 2027 defeat the solar credit under Public Law 119-21 ^[12]
Commercial operation	Yes ^[1]	All six gates passed and construction completed	Includes construction-period attrition after close, which this paper does not model

3.3. Gate Two: Offtake and Revenue

The offtake gate is passed when the revenue case supports a coverage ratio and a tax equity or credit buyer yield the counterparties will accept. For contracted solar the instrument is a physical or virtual power purchase agreement with a utility, corporate buyer or subscriber base; for storage, and increasingly for solar, it is a revenue stack of capacity payments, arbitrage, ancillary services and a hedge ^[91, 92, 99]. Four revenue-side failure mechanisms are documented. Basis risk arises when the settlement point of a virtual agreement differs from the project's node and the spread widens with congestion ^[112, 113]. Price erosion arises as added solar lowers the market value of solar, formalised by Hirth ^[50], anticipated by Joskow ^[51], traced through conventional generation by Bushnell and Novan ^[52] and documented for the United States by Millstein *et al.* ^[48], Seel *et al.* ^[47] and Mills *et al.* ^[46]; solar produces in the hours when prices are most often negative, so a price bankable when signed may not cover the debt once production is reduced for curtailment. Termination risk arises when a corporate offtaker exercises or threatens a termination right as the commercial operation date slips, a right whose value real-options valuation ^[64] and the review of agreement types ^[114] both show to be material, and merchant exposure has

always commanded a premium ^[115]. Credit risk arises when the offtaker's rating falls below the lender's threshold ^[66, 116]. Pricing research shows how these risks enter the contract: hedging of corporate agreements ^[112], the agreement types in use and the risk each allocates ^[99, 114, 117], forward pricing under variable supply ^[118], the effect of bundled certificates and contract terms on the levelised cost an agreement must recover ^[119-121], the predictability of green agreements for the buyer ^[122] and the risk of off-site agreements used against price spikes ^[123]. An agreement transfers but does not remove revenue risk, and the residual (basis, shape, curtailment, counterparty) is what the lender sizes against. Generation forecasting improves the production estimate behind the price ^[78, 107, 124], portfolio optimisation diversifies shape risk that a single-asset borrower cannot ^[125-127], and revenue optimisation ^[128], scenario modelling ^[26] and revenue forecasting ^[129-131] determine on the sponsor's side whether the offtake case survives the lender's downside case. For standalone storage the gate is harder because revenue is mostly uncontracted: whether coupled renewable-battery plants are worth more than separate installations depends on the market and the interconnection constraint ^[91, 92],

hybrid development interacts with congested local transmission ^[132], and the arbitrage value of storage in PJM was estimated long before the current fleet existed ^[133]. Degradation under hot and weak-grid conditions ^[134] and the control architecture of distributed storage ^[135, 136] limit the capacity that can be warranted to a tolling counterparty, so lenders size debt against a contracted floor and treat merchant upside as equity return, which lowers leverage and raises the sponsor capital required at gate five ^[38, 40].

3.4. Gate Three: Tax Credit Qualification

The tax credit gate is passed when counsel can opine that the facility will qualify for the credit rate the model assumes, including any bonus, and that the beginning-of-construction, prevailing wage and apprenticeship, domestic content and prohibited foreign entity conditions are met. Before 2025 the gate had become easier: the Inflation Reduction Act created sections 45Y and 48E, added 10 percentage point energy community and domestic content adders to the 30 percent base credit for projects meeting prevailing wage and apprenticeship requirements, and introduced transferability under section 6418 ^[6, 7, 9]. The investment tax credit is an expensive instrument with cheaper alternatives ^[6, 137], disruptive changes to a credit regime alter investment timing ^[138] and the climate and air quality benefits of the supported capacity are large ^[139]; for a developer the credit is the largest source of capital after debt and its qualification is a condition precedent to every other funding.

Public Law 119-21 reversed the direction. For wind and solar it terminates the sections 45Y and 48E credits for facilities placed in service after December 31, 2027 unless construction began by July 4, 2026, while storage retains the original phase-down beginning in 2034 ^[12, 93]. Executive Order 14315 of July 7, 2025 instructed the Treasury to prevent circumvention of those deadlines through broad safe harbours ^[13], and IRS Notice 2025-42 of August 15, 2025 removed the five percent safe harbour for wind and solar facilities above 1.5 MW AC and made physical work of a significant nature the sole beginning-of-construction test from September 2, 2025, with off-site work counting only under a binding written contract, preliminary activities such as permitting and site clearing not counting, and a four-year continuity safe harbour ^[8, 14]. A solar developer without physical work by July 4, 2026 therefore faces a placed-in-service deadline of December 31, 2027 that few projects with an unexecuted interconnection agreement can meet.

The prohibited foreign entity rules add a second condition: ownership and control restrictions apply from 2026, material assistance restrictions apply to facilities beginning construction after December 31, 2025 (non-prohibited cost ratio of 40 percent in 2026 rising to 60 percent from 2030 for qualified facilities, 55 rising to 75 percent for storage),

transfers to specified foreign entities are barred, and domestic content thresholds were accelerated to 45 percent for construction begun from June 16, 2025, 50 percent in 2026 and 55 percent thereafter ^[12]. Each condition converts a procurement decision into a credit qualification decision, so procurement governance, supplier risk, sustainability metrics and contract compliance frameworks ^[62, 73, 140-144] are now reviewed by tax counsel as well as the independent engineer, and tax governance, cross-border compliance ^[145, 146] and compliance adaptation frameworks ^[147, 148] describe the control environment a transfer buyer expects; a buyer who cannot see it discounts the credit or declines.

3.5. Gate Four: Credit Qualification and Lender Diligence

The credit gate is passed when the construction lender, the term lender and the tax equity investor or credit buyer have completed diligence and their credit committees have approved the transaction on terms consistent with the sponsor's model. The project finance literature identifies the core of the credit decision as the debt service coverage ratio applied to a downside production and price case ^[38-40]. Firouzi and Meshkani ^[38] optimise the debt service schedule against coverage constraints, Mora *et al.* ^[39] show how resource uncertainty feeds debt sizing and Jadidi *et al.* ^[40] catalogue risk mitigation in utility-scale solar project finance; the determinants of project finance success ^[65], the binding role of investor risk perception and type ^[66, 116], the finding that green finance delivers nothing unless risk is taken somewhere in the structure ^[149], production-risk pooling and hedging ^[126, 127] and geospatial screening on project finance tests ^[150] complete the picture.

Lender diligence has a fixed shape that the due diligence literature describes in general terms ^[63, 72, 151, 152]. Table 4 maps the standard items to the failure modes they detect; the reader should see in it that every item has a named performer and gate, which is what makes the credit gate the point at which findings elsewhere are priced: an EPC contract whose schedule guarantee does not cover the placed-in-service deadline ^[61, 73, 74], a module contract exposed to duties or Uyghur Forced Labor Prevention Act detention ^[11, 69, 140], a critical path that cannot absorb the interconnection date ^[58-60], a cost estimate blind to tariffs ^[153-155], or a safety and environmental programme an insurer will not underwrite ^[96, 156-160]. The supply chain literature on EPC projects ^[61, 69] and regulatory-compliant procurement in high-risk energy environments ^[62] transfers directly because the controls are the same: vendor evaluation ^[161-163], materials readiness ^[164], predictive procurement planning ^[165, 166], automation and visibility ^[167-169], digital platforms ^[170-172] and spend analytics ^[155, 173].

Table 4: Standard lender and tax equity diligence items at financial close and the failure modes each is designed to detect.

Diligence item	Performed by	Failure mode detected	Gate affected
Independent engineer production estimate (P50, P90, P99)	Independent engineer	Overstated yield, understated curtailment, degradation assumptions	Offtake, credit
Equipment and supply chain review	Independent engineer, counsel	AD/CVD exposure, UFLPA detention risk, prohibited foreign entity content, warranty gaps	Credit, tax credit
EPC contract review	Counsel, independent engineer	Missing schedule guarantee, inadequate liquidated damages, weak security package	Credit, sponsor capital
Interconnection agreement and upgrade cost review	Counsel, engineer	Unaffordable upgrades, in-service date after deadlines, restudy exposure	Interconnection
Offtake contract review	Counsel, model auditor	Basis risk, termination rights, offtaker credit, curtailment allocation	Offtake
Tax credit eligibility opinion	Tax counsel	Beginning-of-construction failure, bonus credit ineligibility, material assistance breach	Tax credit
Prevailing wage and apprenticeship compliance plan	Counsel, EPC contractor	Credit reduced to one fifth of the rate if requirements are not met	Tax credit
Financial model audit	Model auditor	Formula errors, inconsistent tax assumptions, DSCR below covenant in downside case	Credit
Permits, real estate and title	Counsel, title insurer	Lapsed or contested permits, site control gaps, easement defects	Permitting
Insurance review	Insurance consultant	Uninsurable hail, wildfire or flood exposure; inadequate delay-in-start-up cover	Credit
Sponsor equity commitment and guarantee	Lender credit committee	Insufficient equity, weak completion guarantee, contingent equity not funded	Sponsor capital

The output of diligence is a term sheet whose coverage ratio, tenor, pricing and reserve requirements set the debt the project can carry. Where the diligence findings reduce the production estimate or raise the cost, the debt falls and the equity requirement rises, which is how a credit-gate finding becomes a sponsor-capital failure. Audit and risk governance frameworks that describe risk-based auditing and compliance [28, 29, 32], anomaly detection in financial data [174, 175], unintended consequences of financial regulation [176], procurement risk management in multinational contexts [177, 178] and predictive financial risk assessment [105, 179] describe the same testing logic that a model auditor applies to a project finance model, and the literature on financial reporting, consolidation and treasury control [146, 180-183] describes the reporting covenants that follow close.

3.6. Gate Five: Sponsor Capital and Development Cost

The sponsor capital gate is passed when the developer or its sponsor can fund the equity the credit gate has left, including the lender's contingency and the development costs already spent. It fails in two ways. The first is cost escalation between the development budget and the lender's approved budget: overruns are common across electricity technologies, and solar has performed better than thermal and hydro but is not immune [53, 54]; the project management literature attributes them to optimism bias, scope change and procurement failure [67, 70, 184, 185]; falling module and turbine prices had offset such drift for a decade [68, 186], and the industrial policy behind those declines differs by country in ways that shape supply chain exposure [187]. In 2025 the drivers were module tariffs after the Commerce determinations of April 21, 2025 [11], upgrade costs that rose in cluster restudies [10] and the cost of accelerating physical work to meet the July 4, 2026 deadline [14]. The second is sponsor liquidity: a developer with a large pipeline prunes projects whose expected value no longer justifies the next tranche, which is how a portfolio-level capital allocation decision [27, 98, 100] terminates a project that would have passed every other gate.

The applied finance literature on capital allocation, cash flow forecasting and working capital gives the decision rules sponsors apply [27, 181, 188-192]; capital efficiency optimisation, dashboards, financial analytics, planning models and cost management [98, 193-199] are the tools of the continue-or-stop decision; venture and portfolio risk models [63, 71, 152, 200] describe the same choice for early-stage investors; and the behavioural literature on cognitive bias [201, 202] explains why sponsors fund projects past the point at which Equation (6) would stop them. Capital budgeting aligned with field execution [203] and technical due diligence in energy acquisitions [151] show the decision when the project is sold rather than built: the acquirer's diligence reopens every gate.

3.7. Gate Six: Permitting and Community Acceptance

The permitting gate is passed when every approval counsel must opine on is held and no material challenge is pending. Renewable innovation requires socio-political, community and market acceptance together [204], and United States opposition to utility-scale solar has become organised and effective [205]. Siting ordinances materially reduce the land available [206], and siting, resource potential and system evolution jointly determine where projects can be built [207]. Opposition is shaped by procedural fairness and distributional perception rather than proximity [208], by partisan cues [205], by a democratic deficit in siting that organised opponents exploit [209] and by the framing of rural projects as a burden on hosts [210]; wildlife and land use add a further class of permit risk [211], and sponsors underweight these risks at the development stage [212]. Workforce constraints [213], supply chain resilience [214, 215], competing technologies such as hydrogen [216] and joint venture governance [217] add delay risk that is distinct from opposition but detected at the same gate.

The energy transition analytics literature treats community trust as measurable: predicted from observable indicators [76], linked causally to whether projects survive [77] and driven by distributional questions [95, 218]. Compliance frameworks for renewable projects [96, 97, 219-222],

ESG-integrated procurement ^[223, 224] and safety governance in energy facilities ^[225, 226] describe the record that permitting authorities and insurers examine. For the closing sequence the point is that a late permit challenge delays close until resolved, and under the 2025 to 2027 deadlines one lost construction season can make a viable solar project unable to

reach service by December 31, 2027 ^[12, 14].

Table 5 brings the six gates together as the failure taxonomy that answers RQ1; the reader should see in it that the evidence column is quantitative for only three of the six gates, the gap Section 4.6 addresses.

Table 5: Closing-gate failure taxonomy for United States utility-scale solar and storage projects.

Gate	Enforcing counterparty	Principal failure mechanisms	Evidence on frequency or magnitude	Controls applied at close
1. Interconnection	Transmission provider, FERC	Study delay, unaffordable network upgrades, in-service date after deadlines, curtailment at node	77 percent of 2000-2019 requests withdrawn; median request-to-COD above four years ^[1]	Cluster study results, upgrade cost cap in model, withdrawal penalty exposure, curtailment haircut
2. Oftake and revenue	Offtaker, lender, tax equity	Basis risk, price erosion, termination rights, offtaker credit, merchant storage revenue uncertainty	Declining solar market value and negative prices in high-penetration regions ^[47, 48]	Downside price case, basis hedge, contracted floor for storage, offtaker rating threshold
3. Tax credit qualification	Tax counsel, credit buyer, IRS	Beginning-of-construction failure, bonus credit ineligibility, material assistance breach, PWA non-compliance	Deadlines of July 4, 2026 and December 31, 2027 for wind and solar ^[12, 14]	Tax opinion, physical work documentation, supplier certifications, PWA compliance plan
4. Credit qualification	Lender, independent engineer, model auditor	Production estimate reduction, cost escalation, EPC contract weakness, equipment supply risk, insurance gaps	Cost overruns common across electricity infrastructure ^[53, 54]	DSCR sizing on P90, reserves, EPC security, supply chain review
5. Sponsor capital	Sponsor investment committee	Equity requirement above capacity, development cost drift, portfolio pruning	Portfolio capital allocation rules ^[27, 98]	Contingent equity, completion guarantee, project sale
6. Permitting and community acceptance	Local and state authorities, courts, insurers	Siting ordinances, organised opposition, permit litigation, environmental and wildlife conditions	Siting ordinances reduce available land; opposition organised and effective ^[206, 209]	Permit matrix in counsel opinion, community benefit agreements, litigation reserve

3.8. Gate survival model

The six gates are modelled as a sequence a project must pass in full. Let p_g be the probability that a project which has reached gate g passes it, conditional on having passed the earlier gates; the probability of reaching close from the start of the interval is the product in Equation (1):

$$P_{\text{close}} = \prod_{g=1}^6 p_g \quad (1)$$

The conditional form matters because the gates are not independent. A project that passes the interconnection gate with a late in-service date has a lower pass probability at the tax credit gate than one with an early date, and a project whose diligence reduces the production estimate has a lower pass probability at the sponsor capital gate. The framework captures this through conditioning rather than a correlation structure, which keeps it usable with the coarse information available at the development stage ^[26, 27]. The probability of close for a project that has already passed the first k gates is given by Equation (2), which is the quantity a sponsor compares with the cost of the next tranche of development spend:

$$P_{\text{close}|k} = \prod_{g=k+1}^6 p_g \quad (2)$$

Figure 2 shows the funnel implied by the base-case pass probabilities in Table 6 for the hypothetical portfolio of Section 3.12: of 100 projects entering the interval, an expected 80 pass the interconnection gate and 35 reach financial close. The base case is reconciled with the queue evidence through an explicit identity rather than by matching the 13 percent completion rate directly: if 40 percent of interconnection requests reach the start of this interval (an assumption) and 95 percent of closed projects reach commercial operation (an assumption consistent with construction-period attrition being small), then 0.40 times 0.36 times 0.95 equals 0.14, within one point of the 13 percent completion rate for the 2000 to 2019 cohort ^[1]. The anchor constrains the product of the six pass probabilities, not their individual values, which is why the ranges in Table 6 are wide. The largest single loss is at the interconnection gate, which the queue data support, but the losses between the agreement and close, taken together, are larger. The funnel matters at system level because transmission constraints bind decarbonisation ^[227, 228], the Inflation Reduction Act's emissions impact depends on projects closing ^[229], a zero-emission power sector needs a build rate the current completion rate cannot deliver ^[230, 231], and firm low-carbon resources are needed alongside the variable fleet ^[232].

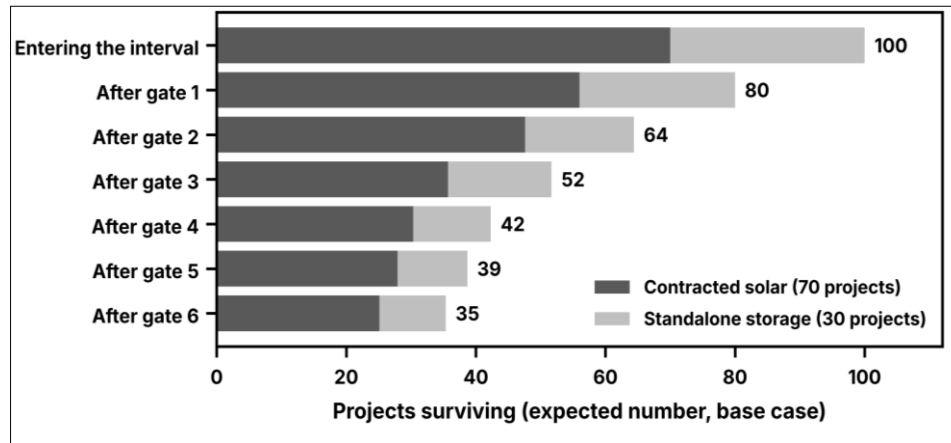


Fig 2: Closing-gate funnel for the hypothetical portfolio of 70 contracted solar and 30 standalone storage projects entering the development-to-close interval, showing the expected number surviving each gate under the base-case pass probabilities in Table 6 (model output, not observed outcomes).

3.9. Debt Sizing and The Credit Gate

The credit gate is the point at which the revenue case is converted into a debt quantum. Lenders size debt by sculpting the debt service to a target coverage ratio against cash flow available for debt service in a downside case. Cash flow available for debt service in period t is defined in Equation (3):

$$CFADS_t = R_t - O_t - M_t - \tau_t \quad (3)$$

where R_t is contracted and merchant revenue net of curtailment and basis, O_t is operating expense including land, insurance and asset management, M_t is major maintenance reserve funding and τ_t is cash tax after credits. The maximum debt the project can carry at a target coverage ratio $DSCR^*$ and all-in interest rate r over tenor T is the present value of the sculpted debt service in Equation (4):

$$D_{\max} = \sum_{t=1}^T \frac{CFADS_t}{DSCR^* (1+r)^t} \quad (4)$$

Equation (4) is the reason the gates interact: a lower production estimate, a curtailment haircut after the cluster study, a wider basis spread or higher insurance cost each lowers $CFADS_t$ and therefore $D_{\max}$, and because capital cost is fixed by the EPC contract the difference is funded by equity at gate five [38-40]. Optimising the debt service schedule against coverage constraints recovers part of the lost quantum [38], and the choice of P90 rather than P50 production changes the debt that can be raised [39]. The tax credit enters through τ_t and through the credit proceeds at close, which Equation (5) expresses for an investment credit sold under section 6418 at a transfer price expressed as a fraction ϕ of face value:

$$V_{ITC} = \phi (\beta_0 + \beta_{EC} + \beta_{DC}) B \quad (5)$$

where β_0 is the base credit rate (30 percent for a facility meeting prevailing wage and apprenticeship requirements), β_{EC} and β_{DC} are the energy community and domestic content adders of 10 percentage points each where earned, and B is the eligible basis [6, 7]. Every condition reviewed in Section 3.4 operates on one of these terms: a beginning-of-construction failure sets the whole expression to zero for a wind or solar facility placed in service after 2027, a prevailing wage failure reduces β_0 to one fifth, a material assistance

breach removes eligibility, and a buyer's diligence finding reduces ϕ [9, 12, 14].

3.10. Development Capital at Risk

The sponsor's decision at each gate is whether to fund the next tranche of development cost given the conditional probability of close. Let c_g be the development spend required to reach and work gate g , and let $S_{g-1} = \prod_{j=1}^{g-1} p_j$ be the probability of having reached gate g . The expected development capital lost on a project is given by Equation (6):

$$E[L] = \sum_{g=1}^6 (\sum_{j=1}^g c_j) S_{g-1} (1 - p_g) \quad (6)$$

Equation (6) states that the expected loss is the cumulative spend to each gate weighted by the probability of reaching and failing it, and it explains two observed behaviours. Sponsors front-load cheap gates and defer expensive ones, because site control and an interconnection request are cheap relative to the readiness deposits, physical work and EPC commitments of later gates [10, 100]; and under the 2025 to 2027 deadlines the sponsor must fund physical work (a large c_3) before the interconnection and offtake gates are resolved, which raises $E[L]$ for every project that later fails gates one or two and is how the beginning-of-construction deadline transfers risk from the Treasury to the developer [8, 14]. The capital allocation and forecasting literature supplies the rules under which sponsors manage this exposure across a pipeline [27, 98, 188, 189], and portfolio optimisation across technologies diversifies it [125, 126].

3.11. Sensitivity of Close Probability to Gate Pass Rates

Table 6 gives the low, base and high pass probabilities assumed for each gate and the rationale and status of each value; the reader should see in it that every value is an assumption bounded by evidence rather than an estimate, and that the product for contracted solar falls from 0.43 to 0.29 when only the tax credit gate moves from 0.90 to 0.60. Figure 3 varies each gate's pass probability from 0.5 to 1.0 while holding the others at base case, with a shaded band showing the 5th to 95th percentile of the other gates' product under the triangular draws of Section 3.12. Because Equation (1) is multiplicative, each curve's slope is the product of the other five pass probabilities, so a gate's influence on close

probability in this design is a property of the assumed base case, not an independently estimated effect: the gate with the lowest assumed value has the steepest curve. Two conditional results follow for the 2026 to 2027 window and answer RQ2 under the assumptions stated. First, the tax credit gate, whose base-case value was close to one under the Inflation Reduction Act, now has a pass probability that depends on whether physical work can be performed before July 5, 2026, and a project for which that probability falls to 0.6 loses roughly a third of its close probability regardless of how well

it performs at every other gate^[12, 14]. Second, for standalone storage the credit gate replaces the tax credit gate as the dominant sensitivity because the credit itself is secure through 2033 while the merchant revenue stack is not^[12, 91, 92]. The width of the band in Figure 3 is the honest measure of what the design can and cannot say: a 0.1 change in the base case of any one gate moves the close probability by less than the band's width, so the ordering of gates is robust to the assumptions but their numerical dominance is not.

Table 6: Assumed low, base and high gate pass probabilities for contracted solar and standalone storage, with the rationale and evidential status of each value.

Gate	Solar low / base / high	Storage low / base / high	Rationale and status
1. Interconnection	0.70 / 0.80 / 0.88	0.70 / 0.80 / 0.88	Assumption bounded by queue evidence: conditional on an executed agreement being obtainable within the deadline; withdrawal before this point is excluded ^[1]
2. Offtake and revenue	0.75 / 0.85 / 0.92	0.55 / 0.70 / 0.82	Assumption: contracted solar revenue is underwritable; merchant storage requires a contracted floor ^[91, 92]
3. Tax credit qualification	0.60 / 0.75 / 0.90 (0.90 before July 2025)	0.90 / 0.95 / 0.98	Assumption bounded by statute: wind and solar deadlines of July 4, 2026 and December 31, 2027; storage phase-down from 2034 ^[12, 14]
4. Credit qualification	0.75 / 0.85 / 0.92	0.65 / 0.75 / 0.85	Assumption: production and cost findings in diligence; merchant storage sized on contracted floor ^[38, 40]
5. Sponsor capital	0.85 / 0.92 / 0.97	0.82 / 0.90 / 0.95	Assumption: equity requirement after diligence; portfolio pruning ^[27, 98]
6. Permitting and community acceptance	0.82 / 0.90 / 0.95	0.90 / 0.95 / 0.98	Assumption bounded by the acceptance literature: solar land use draws more opposition than storage ^[206, 209]
Product (Equation 1), base	0.36 (0.43 at tax credit 0.90; 0.29 at 0.60)	0.34	Finding of the model, conditional on having reached the interval studied here
Product, all low / all high	0.17 / 0.62	0.17 / 0.56	Scenario range, finding of the model

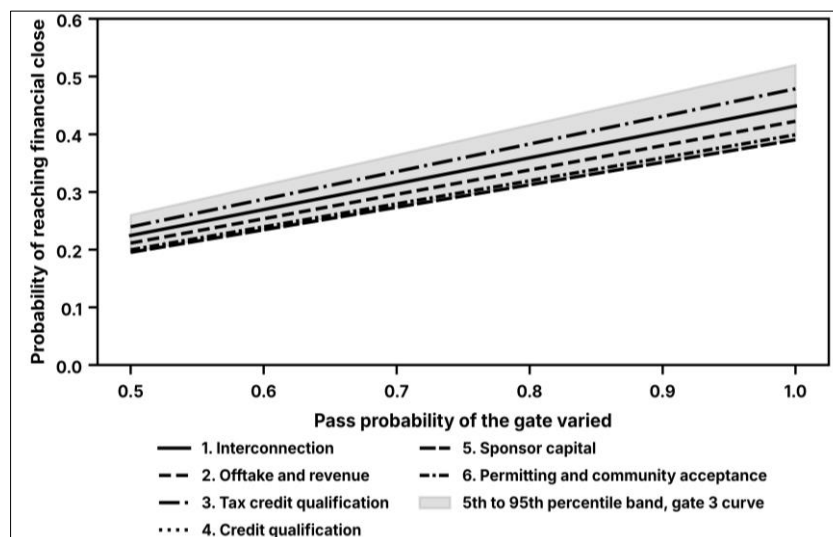


Fig 3: Sensitivity of the probability of reaching financial close to the pass probability of each gate, with the other gates held at the contracted-solar base case in Table 6; the shaded band is the 5th to 95th percentile of the product of the other five gates under the triangular draws of Section 3.12 (model output).

3.12. Worked Portfolio Example, Uncertainty and Correlated Scenarios

The model is worked through a hypothetical portfolio of 100 projects that have each reached the start of the interval: 70 contracted utility-scale solar projects and 30 standalone merchant storage projects, a mix that reflects the two technologies' shares of active queue capacity at the end of 2024^[1]. Table 7 gives the complete survival calculation at the base case; the reader should see in it that the expected number

of survivors falls from 100 to 35 and that the three largest absolute losses are at the interconnection gate (20 projects), the tax credit gate for solar (12 projects) and the offtake gate for storage (7 projects). The calculation is Equation (1) applied gate by gate: 70 times 0.80 gives 56 solar projects after gate one, 56 times 0.85 gives 47.6 after gate two, and so on to 25.1 at close. Under Equation (6) with the spend assumptions in Table 10, the expected development capital lost per solar project is about \$0.9 million of a \$3.0 million

budget, concentrated at the tax credit gate because the physical work required by Notice 2025-42 is the largest

tranche and is committed before gates one and two are resolved ^[8, 14].

Table 7: Worked survival calculation for the hypothetical 100-project portfolio at the base-case pass probabilities in Table 6 (expected numbers, model output).

Gate	Solar pass probability	Storage pass probability	Solar projects surviving	Storage projects surviving	Portfolio surviving
Entering the interval			70.0	30.0	100.0
1. Interconnection	0.80	0.80	56.0	24.0	80.0
2. Offtake and revenue	0.85	0.70	47.6	16.8	64.4
3. Tax credit qualification	0.75	0.95	35.7	16.0	51.7
4. Credit qualification	0.85	0.75	30.3	12.0	42.3
5. Sponsor capital	0.92	0.90	27.9	10.8	38.7
6. Permitting and community acceptance	0.90	0.95	25.1	10.2	35.4
Close probability (Equation 1)	0.359	0.341			

Table 8 reports the uncertainty around that base case. Each gate's pass probability was drawn 10,000 times from a triangular distribution on the low, base and high values in Table 6 and the number of closes was drawn binomially; the 5th to 95th percentile interval for the portfolio is 25 to 43 projects, the mean is 33.6 rather than 35.4 because the

triangular distributions are skewed towards their lower bounds, and the all-low and all-high scenario corners are 16 and 60. The interval, not the point value, is the result to quote: under the stated assumptions roughly one project in three entering the interval closes, with a plausible range from one in four to two in five ^[26, 27].

Table 8: Scenario range and Monte Carlo interval for the number of projects reaching financial close out of 100 (10,000 draws, triangular distributions on the ranges in Table 6, binomial outcomes; model output).

Case	Solar close probability	Storage close probability	Expected closes out of 100	5th to 95th percentile
All gates at low values	0.165	0.166	16.5	not applicable (deterministic)
All gates at base values	0.359	0.341	35.4	not applicable (deterministic)
All gates at high values	0.618	0.560	60.0	not applicable (deterministic)
Monte Carlo, independent draws	0.341 (0.278 to 0.411)	0.325 (0.265 to 0.387)	33.6	25 to 43

Correlated risk is handled in two steps because the gates are not independent in practice: a cluster-study delay pushes the in-service date past the credit deadline and strains sponsor liquidity at once ^[1, 12]. First, the interconnection, tax credit and sponsor capital gates share a common factor through a Gaussian copula with pairwise correlation 0.3 or 0.6; second, three named stress scenarios fix particular gates at their low or high values. Table 9 reports the results; the reader should see in it that correlation among the uncertain pass probabilities alone barely moves the expected count (33.6 to 33.8), because the expectation of a product is only weakly

affected by correlation of its terms, whereas the named scenarios move it substantially: a cluster-study delay that also defeats the solar credit deadline cuts expected closes to 25.5 (interval 18 to 33), capital tightening cuts them to 27.7, and early physical work raises solar close probability to 0.38 but lowers storage's because the committed capital is unavailable at gate five. The dependence that matters is therefore dependence of outcomes within a project, which Section 3.8 captures through conditioning, and the interaction of the 2025 deadlines with a slow cluster study is the scenario a portfolio manager should price first ^[10, 14].

Table 9: Correlated-risk scenarios for the hypothetical portfolio: common-factor correlation among gates 1, 3 and 5 and named stress cases (10,000 draws each; model output).

Scenario	Dependence and fixed values	Solar close probability	Storage close probability	Expected closes	5th to 95th percentile
S0 Independent gates	None; ranges of Table 6	0.341	0.325	33.6	25 to 43
S1 Moderate common factor	Correlation 0.3 on gates 1, 3, 5	0.341	0.325	33.6	24 to 44
S2 Strong common factor	Correlation 0.6 on gates 1, 3, 5	0.344	0.325	33.8	24 to 44
S3 Cluster-study delay	Gate 1 at low for both; solar gate 3 at low; correlation 0.6	0.241	0.287	25.5	18 to 33
S4 Early physical work	Solar gate 3 at high, gate 5 at low; storage gate 5 at low; correlation 0.6	0.381	0.300	35.6	27 to 44
S5 Capital tightening	Gates 4 and 5 at low for both; correlation 0.6	0.285	0.260	27.7	19 to 37

The sequential structure is a modelling choice; in practice permitting, interconnection, financing and tax credit work often proceed at once ^[55, 59]. In a parallel-gate model each gate has an unconditional pass probability q_g , the project fails if any gate fails, and a timing interaction term δ captures the share of projects that pass the interconnection gate with an in-

service date that defeats the credit deadline. The close probability and the expected development loss are given by Equations (7) and (8):

$$P_{\text{par}} = (1 - \delta) \prod_{g=1}^6 q_g \quad (7)$$

$$E[L]_{\text{par}} = (1 - P_{\text{par}}) \sum_{g=1}^6 c_g \quad (8)$$

Table 10 compares the two models; the reader should see in it that they give the same close probability when outcomes are independent and the unconditional probabilities equal the conditional ones, that they differ when outcomes are positively dependent within a project, and that they always differ on expected loss. With independent outcomes Equation (7) at $\delta = 0$ reproduces Equation (1) exactly (0.359 for solar). With positive dependence among the interconnection, tax credit and sponsor capital outcomes the joint pass probability rises to 0.399 at correlation 0.3 and 0.434 at 0.6, because dependence concentrates failures in the same

projects; the sequential model reproduces this only through raised conditional probabilities, which is what conditioning on an early in-service date does in Section 3.8. The timing term works the other way: at $\delta = 0.15$ the solar close probability falls from 0.359 to 0.305, a loss the sequential model attributes to the tax credit gate. On expected loss the models never agree, because the sequential sponsor stops spending at the first failed gate while the parallel sponsor commits the whole budget before any gate resolves: \$0.9 million per solar project under Equation (6) against \$1.9 million under Equation (8). That difference is the economic case for sequencing development spend by Equation (2), and it is what the 2025 deadlines erode by forcing the largest tranche forward ^[14, 98].

Table 10: Sequential and parallel gate models compared for the hypothetical portfolio: development spend assumptions, close probability and expected development loss per project (thousand dollars; model output).

Quantity	Contracted solar	Standalone storage	Note
Development spend to work gates 1 to 6 (thousand dollars)	400; 150; 1,500; 500; 100; 350	same	Assumptions: deposits and site control; origination; physical work; engineer, counsel and model audit; equity process; permits
Close probability, sequential (Equation 1)	0.359	0.341	Base case
Close probability, parallel, independent outcomes (Equation 7, delta = 0)	0.359	0.341	Identical to sequential
Close probability, parallel, correlation 0.3 on gates 1, 3, 5	0.399	0.358	Dependence raises the joint pass probability
Close probability, parallel, correlation 0.6 on gates 1, 3, 5	0.434	0.376	Dependence raises the joint pass probability
Close probability with timing term, delta = 0.15 (solar)	0.305	not applicable	Sequential model attributes the loss to gate 3
Expected development loss, sequential (Equation 6)	901	768	Spend stops at the first failed gate
Expected development loss, parallel, independent (Equation 8)	1,923	1,977	Whole budget committed before resolution
Expected development loss, parallel, correlation 0.6	1,697	1,871	Dependence lowers the loss but it remains about twice the sequential value

3.13. Solar Compared with Standalone Storage

The framework orders the gates differently for standalone storage than for solar, which answers RQ3, and the difference matters because storage held 890 GW of queue capacity at the end of 2024 and is excepted from the wind and solar termination dates ^[1, 12, 93]. Table 11 sets out the comparison gate by gate; the reader should see in it that the direction of relative risk reverses between the tax credit and offtake gates. At the interconnection gate storage benefits from a smaller footprint and substation siting but faces the same cluster study, and in Texas and California storage fleets have themselves created congestion ^[91, 92]. At the offtake gate the difference is structural: solar revenue can be fully contracted, whereas only the capacity element of the storage stack usually is, so the lender sizes debt on the contracted floor and the sponsor funds the rest ^[40, 92]. Degradation and augmentation add a cost term solar lacks ^[108, 134], the levelised cost of storage depends on duty cycle ^[233], cell costs have fallen faster than projected ^[234], and the capacity value

of storage declines as more is added to a region, which caps the contracted floor on which debt is sized ^[235].

At the tax credit gate storage is now the easier case: its 48E credit follows the original phase-down from 2034, although its material assistance threshold starts at 55 percent rather than 40 ^[12], so a storage project beginning construction in 2026 will have a secure credit but a harder supply chain test, shifting the gate's failure mode from timing to procurement ^[62, 140, 142]. At the credit gate storage lenders apply the same coverage logic with a shorter tenor, a larger merchant haircut and closer attention to the supply contract, warranty and augmentation plan, and the independent engineer's review extends to the energy management system and its cybersecurity because revenue depends on dispatch software ^[81, 136, 236-238]; operational technology security ^[236] and predictive maintenance for power infrastructure ^[80, 81, 239, 240] are therefore part of storage diligence in a way they are not for solar.

Table 11: Comparison of closing-gate risk between contracted utility-scale solar and standalone merchant battery storage in the United States, 2026 to 2027.

Gate	Contracted utility-scale solar	Standalone merchant battery storage	Direction of relative risk
Interconnection	Large footprint; in-service date must precede December 31, 2027 unless safe-harboured	Smaller footprint; substation siting; same cluster process	Storage lower
Offtake and revenue	Fully contractable; basis and curtailment residual	Mostly merchant; contracted capacity floor only; arbitrage and ancillary revenue uncertain	Storage higher
Tax credit qualification	Deadlines of July 4, 2026 and December 31, 2027; material assistance 40 percent for 2026 construction	Phase-down from 2034; material assistance 55 percent for 2026 construction	Solar higher on timing; storage on supply chain
Credit qualification	P90 production, module supply, EPC schedule	Contracted floor sizing, warranty and augmentation, energy management system review	Storage higher
Sponsor capital	Equity gap driven by diligence findings and deadline-driven physical work	Equity gap driven by merchant haircut; larger equity share	Storage higher
Permitting and community acceptance	Land use opposition and siting ordinances	Fire safety and setback rules; less land use opposition	Solar higher

The ordering in Table 11 is consistent with the 2024 queue data, in which storage requests fell by 13 percent and solar by 12 percent with the storage decline concentrated where merchant revenue had compressed ^[1], and it explains why hybrids, not always worth more than separate assets ^[91], remain attractive to lenders: solar supplies the contracted floor, storage the upside, and one interconnection position serves both ^[91, 92, 125].

4. Discussion

4.1. Principal Findings Against the Research Questions

The results answer the three research questions in turn. On RQ1, six gates account for attrition between development and financial close, each enforced by an identifiable counterparty and each with a documented failure mechanism: interconnection fails through study duration, upgrade allocation and locational value ^[1, 10, 48]; offtake fails through basis, price erosion, termination and counterparty credit ^[50, 64, 112]; tax credit qualification fails through the beginning-of-construction, material assistance, domestic content and prevailing wage conditions ^[12, 14]; credit qualification fails through diligence findings that reduce cash flow available for debt service ^[38-40]; sponsor capital fails through cost drift and portfolio pruning ^[27, 53]; and permitting fails through siting ordinances and organised opposition ^[206, 209]. On RQ2, the gates interact multiplicatively and through the debt-sizing identity, so that a finding at any gate becomes an equity

requirement at gate five; under the assumed ranges in Table 6 the interconnection and tax credit gates carry the largest losses for solar and the offtake and credit gates for merchant storage, roughly one project in three entering the interval closes (interval 25 to 43 of 100), the correlated scenario that matters most is a cluster-study delay interacting with the credit deadline, and a parallel-gate model gives the same close probability under independence but about twice the expected development loss ^[14, 91]. These are findings of the model under stated assumptions, not estimated effects. On RQ3, the ordering of gates differs between the two technologies: solar carries the timing risk at the tax credit gate and the land-use risk at the permitting gate, whereas storage carries the revenue risk at the offtake gate, the supply chain risk at the tax credit gate and a larger equity share at the sponsor capital gate ^[12, 92, 235]. The single most consequential finding is that a deadline imposed at one gate changes the value of positions held at every other gate, which is the propagation mechanism that prior work had not specified. Table 12 separates, for each main claim of the paper, what rests on published evidence, what is a model assumption and what is a finding of this paper's framework; the reader should see in it that the identification of the gates and their enforcing counterparties rests on evidence, that every probability is an assumption, and that the orderings and the propagation mechanism are findings conditional on those assumptions.

Table 12: Status of the paper's main claims: published evidence, model assumption or finding of this paper.

Claim	Published evidence	Model assumption	Finding of this paper
Six gates with named counterparties and instruments	Statutes, orders, notices ^[10, 12, 14] ; diligence practice ^[38, 40]	None	Grouping into gates (Table 5)
Interconnection is the largest single loss	Queue completion and withdrawal rates ^[1]	Share of withdrawals at gate 1	Attribution of later withdrawals (Table 3)
Gate pass probabilities and their ranges	Direction only ^[1, 12]	All values in Table 6	None
One in three entrants closes, interval 25 to 43	None	Ranges, triangular form, portfolio mix	Tables @7 and @8
Cluster-study delay with the credit deadline is the worst correlated case	Deadlines ^[12, 14] ; study durations ^[1]	Correlation, scenario values	Table 9
Sequential spend halves expected loss relative to parallel commitment	None	Spend per gate (Table 10)	Equations (6), (8); Table 10
Storage ordering differs from solar	Revenue stack and credit rules ^[12, 91, 92]	Storage ranges in Table 6	Table 11
Deadline at one gate propagates to gate 5	Debt-sizing practice ^[39, 40]	None	Equations (4), (6)

4.2. Interpretation and Relation to Prior Literature

Relative to the stage-gate governance models of the project management literature^[55, 56], the framework adds conditional pass probabilities and a named enforcing counterparty at each gate; relative to real-options treatments of energy investment^[64], it replaces the option value of waiting with the expected loss of staged spend under a deadline. The findings agree with Firouzi and Meshkani^[38], Mora *et al.*^[39] and Jadidi *et al.*^[40] that debt sizing is the central problem and Equation (4) is where most gate interactions are priced; the framework adds the conditioning of the credit gate on the gates before it, which those studies take as given because their samples closed. They agree with the de-risking literature that policy instruments move private capital^[41-43] but qualify it: Polzin *et al.*^[41] find that instruments act on investor risk perception, whereas the framework locates the point of action at a gate, so transferability under section 6418 improves the tax credit gate without touching interconnection, while Public Law 119-21 degrades the tax credit gate and, through Equation (6), the sponsor capital gate^[12, 14]. The results disagree with readings of the queue data that treat the 77 percent withdrawal rate as a measure of interconnection failure^[1]: many withdrawals are projects that failed a later gate and surrendered their position, so the queue statistics overstate the interconnection gate's share and understate the later gates'. On risk perception the results support Umamaheswaran *et al.*^[66] and Salm^[11, 6] and locate the perception effects at the credit gate; on community acceptance they support Wüstenhagen *et al.*^[204] and Crawford *et al.*^[209] on the organised character of opposition and add that under the 2025 to 2027 deadlines a permitting delay has a tax credit consequence the earlier acceptance literature could not anticipate^[206, 208].

4.3. Implications for Practice

For developers the first implication is that gates should be worked in the conditional order of Equation (2) rather than the order in which approvals happen to be available; under the 2025 to 2027 deadlines the tax credit gate comes first for wind and solar, because its pass probability is the most sensitive to calendar time and physical work must be documented before July 5, 2026 for any project that cannot be in service by the end of 2027^[8, 14]. That decision commits a large c_3 before gates one and two are resolved, which Equation (6) shows raises expected development loss, so it belongs only to projects whose interconnection and offtake pass probabilities are already high. Second, procurement decisions are now credit qualification decisions: the material assistance ratio, the domestic content threshold and the duty exposure of the module contract each determine whether the credit survives, so the supplier risk, contract review and compliance disciplines of the procurement and legal operations literature^[62, 75, 140, 142, 161, 165, 241-243] must be applied at the development stage; acquirers also examine a sponsor's integration processes^[244-246] and data governance^[247, 248] when a project is sold. Third, pipelines should be managed as portfolios with explicit gate exposures, using the capital allocation and forecasting tools of the financial analytics literature^[27, 37, 98, 188, 193] and the schedule-risk methods of project management^[58-60]; the worked portfolio in Section 3.12 is the template.

For lenders, because the credit gate converts findings at every earlier gate into a debt quantum through Equation (4), the independent engineer's curtailment and production

assumptions and the model auditor's treatment of the tax credit are the items that most often change the deal^[38-40]; risk perception among debt investors^[66] and investor-specific pricing^[11, 6] suggest that part of the sponsor-lender gap is perceptual and that standardised diligence outputs^[28, 30, 32] would narrow it. For credit buyers the transfer price ϕ in Equation (5) should be conditioned on the documentation a tax equity investor would require, because the buyer bears recapture and disallowance risk the seller's indemnity may not cover^[9, 145]. For all three, Section 3.13 implies that storage transactions require a review of the energy management system and its operational technology security^[81, 236] that solar transactions have not included.

4.4. Implications for Theory and Policy

For theory the framework reframes pre-close attrition as a staged-investment problem with conditional survival, connecting renewable project finance to the real-options and capital allocation literatures^[27, 64, 98], and makes three propositions testable: that close probability is multiplicative in gate pass probabilities, that the gate with the lowest pass probability dominates its sensitivity, and that a change at one gate propagates to the sponsor capital gate through the debt-sizing identity. It also explains why the risk-perception findings of Umamaheswaran *et al.*^[66] persist: the credit gate aggregates findings from every earlier gate, so perceptual differences compound at close^[11, 6, 149]. For policy the gates interact, so a measure that improves one gate can be offset by a deadline that tightens another: Order No. 2023 was designed to clear speculative projects and shorten studies, and the 2024 fall in active queue volume is consistent with that working^[1, 10]. The termination dates in Public Law 119-21 and the physical work requirement in Notice 2025-42, however, convert a two-year improvement in study time into no improvement for a solar project that cannot be placed in service by the end of 2027, and they shift development risk onto sponsors who must fund physical work before the interconnection outcome is known^[12, 14]. The 2025 changes do not replace the investment tax credit, long argued to be inefficient^[6, 137], with a better instrument but shorten its life, which the framework predicts will reduce close probability for wind and solar but not for storage or gas; the 72 percent rise in gas queue requests in 2024 is consistent with that direction^[1], and the transmission literature's conclusion that grid expansion binds decarbonisation^[227, 230] implies that the interconnection gate will remain the largest single loss regardless of tax policy.

4.5. Limitations

The framework is conceptual and its numerical content is assumed. The gate pass probabilities in Table 6 are not estimated from project data, so the intervals in Table 8 describe the consequences of the stated ranges rather than sampling uncertainty about a population, and the Monte Carlo design cannot narrow them. The sequential structure simplifies a process in which gates are worked in parallel; Section 3.12 shows that the simplification is harmless for close probability under independence and conservative under positive dependence, but costly if the parallel model's expected loss is the better description of how a particular sponsor commits capital. The same counterparty may enforce more than one gate; a lender, for example, enforces the credit gate directly and the offtake and permitting gates through its conditions precedent^[40, 63]. The evidence base is uneven:

interconnection outcomes are documented in aggregate^[1] but withdrawal reasons are not; cost overrun data exist for completed projects^[53, 54] but not for projects that failed before construction; and the tax credit gate's new pass probability cannot be observed until the 2026 and 2027 placed-in-service outcomes are known. The review window closes at September 30, 2025, so later guidance on material assistance or the physical work test is not reflected^[8, 12]. The applied stream consists of conceptual rather than project-level studies, so it establishes which controls apply without measuring how often each fails^[27, 28], and the design does not weight sources by quality, so triangulation guards against a gate resting on one source but not against a shared bias across streams^[65, 66].

4.6. Future Research Agenda

Three lines of research would address these gaps. The first is a project-level dataset of development-stage outcomes, from queue records, permit dockets and counsel-reported close dates, that would let the pass probabilities be estimated and their conditioning tested, starting from the geospatial screening of Langer *et al.*^[150] and the queue methodology of Rand *et al.*^[1]. The second is an event study of the July 4, 2025 enactment and the August 15, 2025 notice on withdrawals and announced closes by technology, testing the prediction that solar and wind close rates fall while storage and gas rates do not, in the manner of Liu *et al.*^[138]. The third compares sponsor and lender model assumptions at close across transactions, in the manner of Umamaheswaran *et al.*^[66], to measure how much credit-gate loss is analytical and how much perceptual. Each draws on the predictive analytics and model and data governance disciplines of financial and infrastructure risk^[147, 175, 179, 213, 249-252]; a fourth line would extend the framework to hybrid projects, where the value of coupling depends on the interconnection constraint^[91] and the two orderings in Table 11 must be combined.

5. Conclusion

United States utility-scale solar and battery storage projects fail between development and financial close because six gates must each be passed, the pass probabilities are conditional on one another, and the counterparties who enforce the gates convert a finding at any gate into a capital requirement at the sponsor capital gate. That answers the first research question. The answer to the second is that the gates interact multiplicatively and through the debt-sizing identity, so that the gate with the lowest pass probability governs the outcome; under the assumed ranges roughly one project in three entering the interval closes, with a plausible range from one in four to two in five, the interconnection gate is the largest single loss while transmission expansion lags deployment, and the tax credit gate became in 2025 the gate with the hardest deadline for wind and solar, requiring physical work by July 4, 2026 or commercial operation by December 31, 2027. A parallel-gate model gives the same close probability but about twice the expected development loss, which is the economic case for sequencing development spend. The answer to the third is that standalone storage faces a different ordering in which merchant revenue and credit qualification dominate and the tax credit is secure. Developers should sequence their work by the conditional structure of the gates, treat procurement as a credit qualification decision and manage pipelines as portfolios of gate exposures; lenders and credit buyers should concentrate

diligence on the production, curtailment and tax assumptions that drive the debt quantum; and policymakers should recognise that a deadline on one gate can cancel an improvement in another. The research agenda is a project-level dataset of development-stage outcomes that would convert the framework's assumed probabilities into estimates, narrow the intervals reported here and allow its three propositions to be tested.

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