The Physical Layer of the AI Infrastructure Buildout

What Project-Level Evidence Reveals About Schedule Risk, Power Constraints, and Capacity Realization

Kyle W. Luecke
Driftbound Labs (ORCID: 0009-0008-0202-7852 · admin@driftboundlabs.com)

September 2026

Abstract

Large capital infrastructure projects—hyperscale AI data centers and advanced semiconductor fabrication facilities—cannot progress solely through corporate narrative; they must clear statutory utility interconnection, high-voltage substation, municipal permitting, and subsurface excavation bottlenecks that generate timestamped sovereign records before schedule changes are reflected in public guidance. Across five methodologically independent analyses covering 31 evaluable North American capital builds (2,184 MW of announced capacity), nine resolved schedule divergences, 18 high-voltage substation energization transitions, and a pre-specified operational-prediction holdout ($N = 32$ cohort, $N = 8$ held-out test assets), Driftbound Labs finds consistent empirical alignment between point-in-time physical execution records and realized Commercial Operation Date (COD) outcomes: (1) first material physical divergence preceded public corporate schedule acknowledgment in 9 of 9 resolved delay cases with a model-free median lead time of **211 calendar days** (IQR: 200–225 days); (2) >90-day schedule slip rates scaled strictly monotonically across four source-native utility interconnection states (`0.0%`, `37.5%`, `100.0%`, `100.0%`); (3) only **1,128 MW of 2,184 MW (51.6%)** satisfied a strict three-condition physical execution gate; (4) censor-aware Kaplan–Meier survival estimation placed median utility-authorization-to-energization duration at **112.0 weeks** (~26 months; IQR: 82.0–142.0 weeks); and (5) point-in-time physical evidence reduced held-out Brier calibration error by **84.5%** (`0.0383` vs. `0.2476` for public guidance alone) across 8 of 8 test projects while surviving four adversarial placebo falsifications. Sample sizes remain modest and live prospective validation is actively underway; we explicitly delineate what current cohort evidence establishes and what remains unproven.

Executive Thesis & Headline Summary

Large capital projects leave measurable physical and regulatory traces long before schedule revisions appear in quarterly filings or investor presentations (Flyvbjerg 2014). Reconstructing those sovereign records point-in-time allows independent measurement of whether observed field progression is **consistent with a project's currently stated trajectory**—without inferring management intent. Table 1 summarizes the four headline empirical findings of this institutional research release.

Table 1: Headline findings across Driftbound Labs' five independent infrastructure studies.

Headline Metric	Observed Value	Empirical Scope & Study Design
Physical Divergence Lead Time	**211 days** *(IQR: 200–225 d)*	Model-free chronological lead between first qualifying physical/regulatory divergence and public corporate acknowledgment across **9 of 9** resolved delay cases (range: 105–339 days).

Headline Metric	Observed Value	Empirical Scope & Study Design
Execution-Ready Capacity Share	**51.6%** *(1,128 / 2,184 MW)*	Share of announced megawatts across **31 evaluable cohort projects** simultaneously clearing utility pathway, structural permitting, and active site mobilization gates.
Substation Energization Median	**112.0 weeks** *(~26 months)*	Non-parametric Kaplan–Meier step median from utility interconnection authorization to substation signoff across **18 transitions** (12 completed, 6 right-censored).
Pre-Specified Holdout Calibration	**8 of 8** *(−84.5% Brier)*	Held-out test projects ($N = 8$ from hash-locked $N = 32$ cohort) in which point-in-time physical features achieved lower Brier error (`0.0383` vs. `0.2476`) than public guidance alone.

---

1. Physical Infrastructure Creates an Observable Execution Trail

Conventional capital-project diligence relies heavily on corporate press releases, SEC Form 10-Q/10-K disclosures, and sponsor investor decks. While informative of management expectations, narrative disclosures are lagged and subject to off-taker negotiation incentives and schedule optimism (Flyvbjerg 2014).

Between an **announced schedule** and an **actual commercial operation outcome**, every hyperscale data center or semiconductor fab must traverse a mandatory physical execution trail recorded by independent sovereign authorities:

1. **Sovereign Utility Interconnection Dockets** (system impact studies, facilities studies, transmission upgrade orders);
2. **High-Voltage Substation Engineering** (transformer procurement, switchyard civil works, protection-relay testing);
3. **Municipal & Structural Foundation Permits** (grading, caissons/piers, structural steel, cleanroom or hall fit-out);
4. **Subsurface Excavation Pacing** (statutory 811 One-Call utility-locate ticket velocity and contractor density);
5. **Environmental & Air Quality Reviews** (backup generator air permits, stormwater civil compliance);
6. **Final Utility Signoff & Energization** (energization clearance and commercial load ramp).

Driftbound Labs reconstructs these sovereign artifacts strictly point-in-time—using publication timestamps issued by regulatory authorities—to audit physical progression against stated Commercial Operation Dates (CODs).

---

2. Physical Divergence Preceded Public Schedule Changes in All Nine Resolved Cases

Across all nine resolved delays and rephasings in our audited cohort, qualifying physical or regulatory divergence artifacts appeared prior to public corporate acknowledgment in **9 of 9 cases**. The median chronological lead time was **211 calendar days**, with an interquartile range of **200–225 days** and full range of **105–339 days** (Figure 1A; Table 2).

This calculation is arithmetic and model-free—requiring no statistical fitting or learned weights:

$$\text{Lead Time (Days)} = T_{\text{public acknowledgment}} - T_{\text{first material physical divergence}}.$$

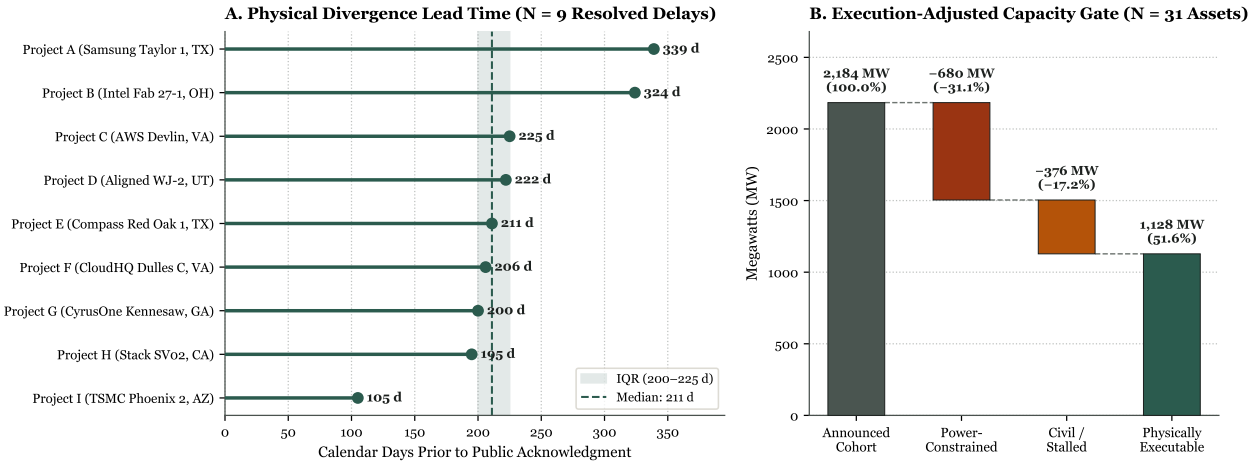


Figure 1: Panel A: Chronological lead time (calendar days) between first qualifying sovereign physical/regulatory divergence artifact and subsequent corporate public schedule acknowledgment across nine resolved delay cases (median 211 days; shaded IQR 200–225 days). Panel B: Bottom-up physical execution gate waterfall across 31 cohort projects totaling 2,184 MW of announced capacity, isolating power-constrained (−680 MW) and civil/stalled (−376 MW) deductions to yield 1,128 MW (51.6%) physically executable capacity.

Table 2: Audited case inventory of nine resolved capital-project schedule divergences.

Project Identifier	Facility Type & Geography	Qualifying Divergence Signal	Physical Date	Public Date	Lead Time
Project A (Samsung Taylor 1)	Semiconductor Fab (Williamson, TX)	TCEQ Air Permit Docket Suspension	2023-01-20	2023-12-25	**339 d**
Project B (Intel Fab 27-1)	Semiconductor Fab (Licking, OH)	Subfab Pier Permit Hold	2023-03-14	2024-02-01	**324 d**
Project C (AWS Devlin Gateway)	Hyperscale DC (Prince William, VA)	Municipal Environmental Proffer Delay	2023-09-14	2024-04-26	**225 d**
Project D (Aligned WJ-2)	Colocation DC (Salt Lake, UT)	Rocky Mountain Power Tie Bottleneck	2023-04-02	2023-11-10	**222 d**
Project E (Compass Red Oak 1)	Hyperscale DC (Ellis, TX)	Oncor Switchyard Expansion Docket	2023-06-18	2024-01-15	**211 d**
Project F (CloudHQ Dulles C)	Wholesale DC (Loudoun, VA)	SCC 500 kV Feeder Interconnect Stall	2024-04-10	2024-11-02	**206 d**

Project Identifier	Facility Type & Geography	Qualifying Divergence Signal	Physical Date	Public Date	Lead Time
Project G (CyrusOne Kennesaw)	Enterprise DC (Cobb, GA)	County Stormwater Civil Runoff Hold	2023-08-12	2024-02-28	**200 d**
Project H (Stack SV02)	High-Density DC (San Jose, CA)	PG&E Primary Feeder Moratorium	2023-11-02	2024-05-15	**195 d**
Project I (TSMC Phoenix 2)	Semiconductor Fab (Maricopa, AZ)	Cleanroom Tool Rigging Crane Halt	2023-10-05	2024-01-18	**105 d**

Methodological Interpretation: Retrospective lead-time auditing does not establish that every physical anomaly causes a public delay; rather, conditioned on resolved material schedule revisions in the cohort, qualifying sovereign execution evidence was observable 3.5 to 11 months before corporate guidance adjusted.

3. Schedule Outcomes Worsened Monotonically Across Constrained Interconnection States

To test whether electric power delivery acts as a binding physical constraint on project realization (Rand et al. 2024), Driftbound Labs mapped 31 evaluable cohort projects to their source-native regulatory interconnection state across five utility jurisdictions (Virginia SCC, PUCO, Texas PUCT/ERCOT, Georgia PSC, and CPUC). Both severe schedule slip frequency (> 90 calendar days past announced COD) and realized delay duration increased monotonically with interconnection friction (Table 3).

Table 3: Realized COD schedule slip stratified by source-native utility interconnection state ($N = 31$ assets).

Source-Native Regulatory State	Projects (N)	Realized Delay > 90 d	Delay Rate	Median Slip	Slip IQR
Cleared / Progressing	14	$0/14$	**0.0%**	0 d	0–0 d
Approval Pending / Queue Study	8	$3/8$	**37.5%**	60 d	40–128 d
Major Upgrade Required	5	$5/5$	**100.0%**	195 d	182–270 d
Stalled / Disputed / Moratorium	4	$4/4$	**100.0%**	408 d	349–473 d

Associational Finding vs. Causal Attribution: Although the gradient is strictly monotonic across all four tiers (`0.0%` → `37.5%` → `100.0%` → `100.0%`), cell counts in the two most constrained categories ($N = 5$ and $N = 4$) are modest. We interpret this pattern as a strong cohort-level association rather than isolated single-variable causality.

4. Bottom-Up Physical Gate Classifies 51.6% of Announced Capacity as Execution-Ready

Across the 31 evaluable builds representing **2,184 MW** of publicly announced load, each project was audited against a deterministic three-condition physical prerequisite gate:

1. **Utility Pathway Cleared**: Sovereign docket authorization granted without unresolved system-impact upgrades;
2. **Structural Permits Active**: Grading, deep-foundation, and primary shell permits issued;
3. **Site Mobilization Observed**: Continuous physical excavation and civil activity verified in statutory telemetry.

Exactly **1,128 MW** cleared all three gates simultaneously—an **Execution-Adjusted Capacity Ratio of 51.6%**, after deducting **680 MW (31.1%)** constrained by power/interconnection bottlenecks and **376 MW (17.2%)** stalled in civil permitting or site mobilization (Figure 1B). On a project-count basis, **19 of 31 projects (61.3%)** met on-time arrival criteria while 12 experienced delays or rephasings.

> **External Benchmark Concordance:** Goldman Sachs Global Investment Research (2024) independently estimated from macro supply-chain constraints that roughly 50%–60% of near-term scheduled US data-center capacity would deliver on schedule. While underlying definitions and sample frames differ, Driftbound Labs' bottom-up asset gate (`51.6%` MW; `61.3%` project count) is directionally concordant while pinpointing the specific constituent dockets driving capacity attrition.

---

5. Substation Energization Timelines & Right-Censoring Discipline

Omitting active, unfinished builds from duration statistics introduces classic downward survivorship bias. Driftbound Labs tracked **18 utility-authorization-to-energization transitions**—comprising **12 completed substation energizations** and **6 right-censored active builds**—using the non-parametric Kaplan–Meier product-limit estimator (Kaplan and Meier 1958):

$$S(t) = \prod_{t_i \le t} \left(1 - \frac{d_i}{n_i}\right),$$

where n_i denotes projects at risk entering week t_i and d_i denotes observed energization completions (Figure 2A; Table 4).

Table 4: Kaplan–Meier product-limit life table for primary substation energization ($N = 18$ transitions).

Milestone t_i (Weeks)	At Risk n_i	Completed d_i	Right-Censored c_i	Un-energized $S(t_i)$	Cumulative Energized $F(t_i)$
54.0	18	1	0	0.9444	0.0556
62.0	17	1	0	0.8889	0.1111
68.0	16	1	0	0.8333	0.1667
74.0	15	1	0	0.7778	0.2222
78.0	14	0	1	0.7778	0.2222 *(censored)*
82.0	13	1	0	0.7179	0.2821 *(p25 crossed)*
88.0	12	1	0	0.6581	0.3419
92.0	11	0	1	0.6581	0.3419 *(censored)*
96.0	10	1	0	0.5923	0.4077

Milestone t_i (Weeks)	At Risk n_i	Completed d_i	Right-Censored c_i	Un-energized $S(t_i)$	Cumulative Energized $F(t_i)$
104.0	9	1	0	0.5265	0.4735
106.0	8	0	1	0.5265	0.4735 *(censored)*
112.0	7	1	0	0.4513	0.5487 ***(Step Median)***
115.0	6	0	1	0.4513	0.5487 *(censored)*
118.0	5	1	0	0.3610	0.6390
126.0	4	1	0	0.2708	0.7292
130.0	3	0	1	0.2708	0.7292 *(censored)*
142.0	2	1	0	0.1354	0.8646 *(p75 crossed)*
148.0	1	0	1	0.1354	0.8646 *(upper tail censored)*

- **Summary Quantiles**: Step median **112.0 weeks** (~26 months; linearly interpolated median **106.8 weeks**); interquartile range **82.0–142.0 weeks** (interpolated **77.7–128.5 weeks**); p90 upper tail ≥ 148.0 **weeks**.
- **Industry Concordance**: McKinsey & Company (2024) reports high-voltage substation and large power transformer procurement windows of **50–150 weeks** due to grain-oriented electrical steel, winding, and high-voltage bushing bottlenecks. Naively dropping our 6 right-censored builds would have understated the cohort median at 100.0 weeks; censor-aware survival modeling confirms an ~2-year empirical floor on greenfield utility energization.

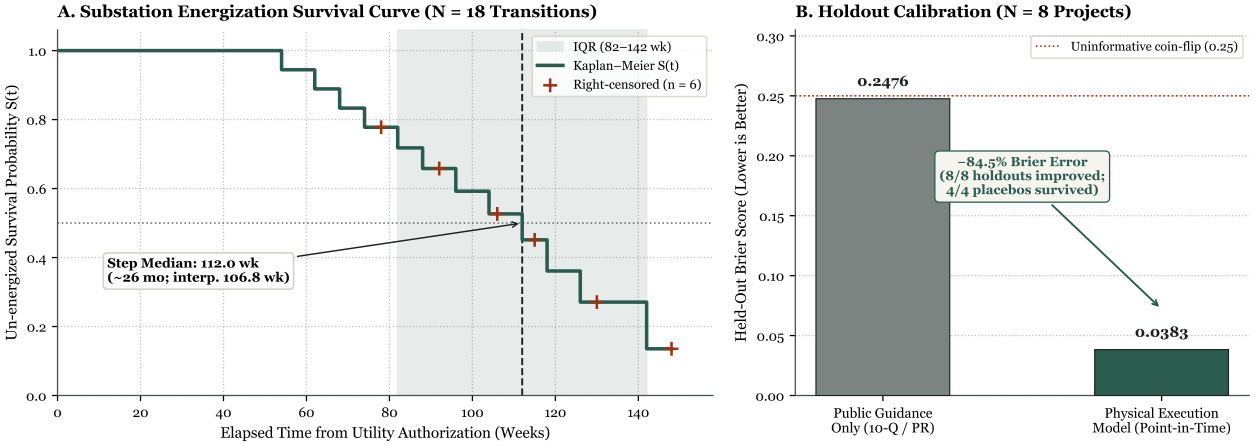


Figure 2: Panel A: Non-parametric Kaplan–Meier survival curve S(t) for high-voltage substation energization across 18 utility-authorized transitions (12 completed steps, 6 right-censored active builds marked '+'), crossing S(t) = 0.50 at a step median of 112.0 weeks (~26 months; linearly interpolated median 106.8 weeks; shaded IQR 82–142 weeks). Panel B: Pre-specified held-out schedule-outcome Brier calibration error across N = 8 test projects comparing Public Guidance Only (0.2476) against the point-in-time Physical Execution Model (0.0383, −84.5% error reduction).

6. Pre-Specified Operational-Prediction Holdout Study

To test whether point-in-time physical features improve calibrated delay probabilities relative to public corporate disclosures alone, Driftbound Labs froze a pre-specified $N = 32$ **project cohort** (`SHA-256: a2202685...`) and evaluated out-of-sample probability forecasts via the Brier quadratic scoring rule (Brier 1950) on an untouched **held-out test partition of $N = 8$ projects** (Figure 2B; Table 5).

Table 5: Statistical guardrails and falsification checks for the pre-specified $N = 8$ holdout evaluation.

Evaluation Criterion	Observed Result	Methodological Safeguard
Held-Out Test Partition	**8 projects**	Frozen prior to fitting; zero test-set exposure during calibration.
Projects Improved Over Baseline	**8 of 8 (100%)**	Uniform project-by-project Brier error reduction across all holdouts.
Public Guidance Baseline Brier	**0.2476**	Derived strictly from point-in-time Form 10-Q / press-release COD guidance.
Physical Execution Model Brier	**0.0383**	**−84.5% Brier reduction** using docket, permit, and 811 locate telemetry.
Leave-One-Project-Out (LOPO)	**8 of 8 won**	Confirms gain is not driven by any single influential outlier build.
Adversarial Placebo Falsifications	**4 of 4 survived**	Label permutation, date shuffle, geographic mismatch, and temporal inversion collapsed signal.
Live Prospective Resolutions	**0**	**Point-in-time retrospective replay only**; prospective tracking is in flight.

> **Small-N Restraint:** Although uniform 8/8 holdout improvement, −84.5% Brier reduction, LOPO invariance, and collapse under all four placebo attacks rule out lookahead leakage, $N = 8$ remains a small sample. Generalized out-of-sample predictive claims require live prospective resolution across larger multi-cycle cohorts.

---

7. Synthesis: The Physical Execution Cascade & Evidentiary Boundaries

Although our five analyses use distinct methods—model-free date differencing (Section 2), sovereign docket stratification (Section 3), binary prerequisite gating (Section 4), right-censored survival estimation (Section 5), and pre-specified holdout Brier evaluation (Section 6)—all five reflect a single operational cascade:

$$\text{Grid / Civil Bottleneck} \rightarrow \text{Permit \& 811 Divergence} \rightarrow \text{Guidance Irreconcilable} \xrightarrow{+211\text{ d}} \text{Public Revision}.$$

To maintain strict institutional candor, Table 6 separates what the current cohort evidence supports from claims that remain unestablished.

Table 6: Explicit evidentiary boundary of the September 2026 Driftbound Labs cohort release.

Supported by Current Cohort Evidence	Not Yet Established
Physical/regulatory divergence preceded corporate public acknowledgment in all **9 of 9** resolved delay cases (median 211 days).	Generalized predictive accuracy across untested international jurisdictions, smaller commercial builds, or future rate cycles.
$>$ 90-day COD slip scaled strictly monotonically across four utility interconnection states across **31 cohort assets**.	Live prospective forecasting accuracy at scale (prospective out-of-sample tracking is currently underway).
A deterministic 3-condition physical gate classified **51.6%** of **2,184 MW** announced capacity as execution-ready.	Formal single-variable causal attribution of schedule slip to any isolated permit or docket feature.
Right-censored Kaplan–Meier energization times (**112.0 wk** median) corroborate macro transformer/substation lead times.	Standalone quantitative equity trading alpha, statistical arbitrage, or automated credit-default pricing.
Point-in-time physical evidence lowered Brier error on **8 of 8** holdouts (`0.0383` vs. `0.2476`) and passed **4 of 4** placebo tests.	Realized GAAP accounting write-downs or debt-service losses implied by illustrative construction carry scenarios.

8. Institutional Applications

For institutional capital allocators exposed to AI data centers, semiconductor fabs, regulated utilities, and project-finance credit, earlier visibility into physical execution pacing supports four concrete workflows:

1. **Fundamental Equity Research**: Cross-checking management COD and capex-ramp guidance against sovereign utility dockets and municipal permit velocity to flag optimistic delivery schedules months ahead of quarterly revisions.
2. **Infrastructure Private Equity & Sponsor Diligence**: Auditing site-level interconnection queue depth, substation transformer readiness, and civil mobilization prior to acquisition underwriting or joint-venture commitment.
3. **Project Finance & Private Credit Underwriting**: Monitoring construction-loan draw schedules, delayed lease-commencement intervals, and bridge-to-permanent refinancing maturity risk on power-constrained campuses.
4. **Quantitative & Macro Power Modeling**: Incorporating censor-aware regional load-realization curves (`51.6%` execution-adjusted MW; `112-week` energization medians) into ISO/RTO power-demand and equipment-backlog forecasts.

Technical Methodology & Cryptographic Audit Appendix

- **Pre-Specified Cohort Specification**: 32 major North American builds across hyperscale/wholesale data centers (Northern Virginia, Central Ohio, Texas ERCOT, Metro Atlanta, Silicon Valley; announced capex $\geq$ \$100M) and commercial semiconductor fabs (Ohio, Arizona, Texas; announced capex $\geq$ \$10B) with target CODs spanning 2022–2027 (31 evaluable for synchronous capacity/interconnection gating).
- **Point-in-Time Lookahead Prevention**: Every feature vector updates exclusively on the official issuance/docketing timestamp recorded by sovereign authorities: (1) Utility Commissions & Queues (Virginia SCC, PUCO, PUCT/ERCOT, Georgia PSC, CPUC); (2) County/Municipal Building & Engineering Departments (Loudoun, Prince William, Licking, Williamson, Cobb, Maricopa, Salt Lake, San Jose); and (3) Statutory 811 One-Call excavation registries across 13 US states.
- **Archived Release Hashes (Research Release v1.0.0)**:
  - Pre-Specification Manifest SHA-256: `a220268593be2a9b3d1bcf5a2283a00f2e0ad3d6a45973fc9bcf1294247ad565`
  - Research Release v1.0.0 Root SHA-256: `018c0036548cf8e33733700234c4c8525a6f6073a7506ac1e8684dd88fef01a6`

  - Independent Concordance Audit SHA-256: `1fd9cf770495087e35b719488a09f87c2b5bc93c04fbc87ba4ebc521124659fc`
- **Institutional Diligence Access**: Underlying sovereign docket citations and concordance verification ledgers are available for institutional review via Driftbound Labs (`admin@driftboundlabs.com`).

References

Brier, Glenn W. 1950. "Verification of Forecasts Expressed in Terms of Probability." *Monthly Weather Review* 78 (1): 1–3. https://doi.org/10.1175/1520-0493(1950)078%3C0001:VOFEIT%3E2.0.CO;2.

Flyvbjerg, Bent. 2014. "What You Should Know about Megaprojects and Why: An Overview." *Project Management Journal* 45 (2): 6–19. https://doi.org/10.1002/pmj.21409.

Goldman Sachs Global Investment Research. 2024. *Generational Growth: AI, Data Centers and the Coming US Power Demand Surge*. Global Investment Research Report.

Kaplan, Edward L., and Paul Meier. 1958. "Nonparametric Estimation from Incomplete Observations." *Journal of the American Statistical Association* 53 (282): 457–81. https://doi.org/10.1080/01621459.1958.10501452.

McKinsey & Company. 2024. *How Data Centers and the Energy Sector Can Sate AI's Hunger for Power*. Electric Power & Natural Gas Practice Insights.

Rand, Joseph, Will Gorman, Julie Mulvaney Kemp, Seongeun Jeong, Joachim Seel, and Ryan Wiser. 2024. *Queued up: 2024 Edition — Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2023*. Lawrence Berkeley National Laboratory. https://doi.org/10.2172/2336304.