

A delivery gap in electricity grid expansion Supplementary Information

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1 SN 1: Evolution of the European grid policy framework (2009–2026)

The 16-year timeline of grid deployment analyzed in this study (2010–2026) aligns with a structural shift in the European Union’s regulatory framework towards the electricity grid. Over this period, European policy transitioned from a reactive, project-by-project approach toward a proactive, integrated governance model aimed at resolving the administrative and coordination bottlenecks quantified in our analysis. Here we describe this transition over four time periods and describe how they shape the TYNDP.

(2009–2015) Institutionalizing supra-national planning through Projects of Common Interest (PCI). The foundation of modern European grid planning was established by the Third Energy Package (Regulation (EC) No 714/2009)¹, which mandated the European Network of Transmission System Operators for Electricity (ENTSO-E) to draft the biennial Ten-Year Network Development Plan (TYNDP). Subsequently, Regulation (EU) No 347/2013² recast the TEN-E framework establishing the current scope of the Project of Common Interest (PCI) status: priority treatment in permitting, cross-border cost allocation, and eligibility for Union financial assistance. To address implementation bottlenecks, this regulation required Member States to designate a national competent authority responsible for facilitating and coordinating the permit-granting process and capped the permit-granting process for PCIs at three years and six months, extendable by a maximum of nine months².

(2016–2020) Analytical tightening and climate-grid alignment Two key institutional changes preceding the 2018 TYNDP reporting cycle directly shaped the pace of project development. First, the revised Environmental Impact Assessment (EIA) Directive (Directive 2014/52/EU³), which Member States had to incorporate into national law by May 2017, streamlined and set statutory time bounds on environmental assessment procedures for applications submitted thereafter. Second, the permitting regime under Regulation (EU) No 347/2013 reached maturity. Because Chapter III capped the permit-granting duration for Projects of Common Interest (PCIs) at three years and six months for post-November 2013 applications, the first cohorts processed entirely under this regime concluded around 2017–2018. Over the same period ENTSO-E’s 2nd Cost–Benefit Analysis (CBA)⁴ Guideline—consulted in 2016 and implemented in the TYNDP 2018 cycle—introduced stricter assessment criteria, leading to the removal of projects whose modelled socio-economic benefits no longer justified inclusion. The subsequent Clean Energy Package further aligned network planning with decarbonization targets. Specifically, Regulation (EU) 2018/1999⁵ mandated transmission and interconnectivity targets (15% by 2030) within National Energy and Climate Plans. In our multi-state Cox model, this regulatory tightening represents a structural break that accelerates phase transitions for spells starting in or after the 2018 cycle. Because this cutoff coincides with the portfolio consolidation documented in Supplementary Note 7, part of this observed acceleration likely reflects the higher baseline maturity of the surviving projects.

(2021–2023) Crisis response and siting certainty Driven by the European Green Deal and the energy crisis, the EU substantially overhauled its spatial and environmental planning. The revised TEN-E Regulation (Regulation (EU) 2022/869)⁶ introduced the category of Projects of Mutual Interest for infrastructure shared with third countries and mandated integrated offshore network plans at the sea-basin level. To counter permitting delays—which our analysis identifies as the primary driver of late-stage schedule overruns (42.6%)—Council Regulation (EU) 2022/2577⁷ established a rebuttable presumption of “overriding public interest” (OPI) for grid development, renewable energy plants, and storage assets. Initially implemented as a temporary emergency measure, this OPI presumption was made permanent by Article 16f of the revised Renewable Energy Directive (RED III, Directive (EU) 2023/2413)⁸. RED III also introduced Renewables Acceleration Areas (RAAs). While RAAs primarily govern the siting of generation rather than the grid, we interpret them as a source of locational certainty that can mitigate stranded-asset risks for transmission promoters. However, the impact of these recent reforms on our observed outcomes is limited: Member States have until 21 February 2026 to designate RAAs, and the transposition of OPI has been highly uneven, with only five Member States establishing it in national law to date.

(2024–2026) Codification of proactive investment and proposed queue reform. The most recent policy phase addresses the “generation–transmission dilemma” and the high cancellation rates (nearly 50%) observed in our dataset. To tackle this, the 2024 Electricity Market Design reform (Regulation (EU) 2024/1747⁹) mandated that network charges provide both short- and long-term incentives, explicitly including anticipatory investments. The European Commission reinforced this with non-binding guidance (Commission Notice C/2025/3179¹⁰), urging Member States and regulators to integrate these anticipatory investments into their network planning and cost-approval frameworks. Furthermore, the European Grids Package¹¹ presented on 10 December 2025 addresses our finding that the institutional pipeline is congested with speculative proposals. Through a dedicated Commission Notice (C/2025/8473), it recommends shifting grid connections from a “first-come, first-served” to a maturity-based “first-ready, first-served” approach. This shift is to be supported by strict project-development milestones, financial penalties, and regular queue cleaning. The binding legislative components of this package—a proposal replacing the TEN-E Regulation (COM(2025) 1006 final) and a permitting-acceleration Directive (COM(2025) 1007 final)—remain under ordinary legislative review at the time of writing. Crucially, these queue reforms primarily target generation connection queues rather than the transmission investment pipeline itself. Consequently, their impact on the infrastructure dynamics analysed in our study is indirect and entirely prospective.

2 SN 2: Data sources

Table 1 reports the sources for each TYNDP edition included in the analysis. The core TYNDP tables were complemented, whenever available, with *Monitoring Updates (MU)* and TYNDP draft project portfolio.

To complete the 2018 report data we scraped missing variables (evolution driver, delay explanation) from the 2018 cycle directly from ENTSO-E web pages using Selenium and BeautifulSoup. We tracked discontinued investments via official “Non-submitted” and “Non-compliant” lists in the 2020-2026 TYNDP Draft Project Portfolios.

Table 1: Data sources for the TYNDP 2010–2026 editions

Year	Source
2010	ENTSO-E TYNDP 2010
2012	ENTSO-E TYNDP 2012
2012 MU	ENTSO-E TYNDP Monitoring Update 2012
2014	ENTSO-E TYNDP 2014
2014 MU	ENTSO-E TYNDP Monitoring Update 2014
2016	ENTSO-E TYNDP 2016
2018	ENTSO-E TYNDP 2018
2018	ENTSO-E TYNDP 2018-webpage for web-scraping
2020 Draft project portfolio	ENTSO-E TYNDP 2020
2020	ENTSO-E TYNDP 2020
2022 Draft project portfolio	ENTSO-E TYNDP 2022
2022	ENTSO-E TYNDP 2022
2024 Draft project portfolio	ENTSO-E TYNDP 2024
2024	ENTSO-E TYNDP 2024
2026 Draft project portfolio	ENTSO-E TYNDP 2026

3 SN 3: Multi-state Cox model: data structuring and assumptions

To bridge the gap between the discrete, biennial nature of the raw TYNDP reports and the strict mathematical assumptions of a continuous-time survival model, we applied two critical data pre-processing steps.

Longitudinal formatting and non-linear transition filtering

To prepare the panel for the multi-state Cox proportional hazards model, the data was restructured into an event-driven counting-process format (T_{start} , T_{stop}). While our transition matrix captures non-linear trajectory artifacts resulting from reporting anomalies (e.g., forward jumps or backward steps), maintaining these structurally discontinuous spells in the subdistribution hazard models would violate the foundational assumptions of sequential progression. Consequently, the multi-state Cox dataset was filtered to evaluate only sequential phase advancements ($i \rightarrow i + 1$), right-censored observation spells ($i \rightarrow i$), and definitive terminal failures ($i \rightarrow 6$).

Computational jittering for zero-length intervals

The biennial granularity of the TYNDP reporting cycle generates discrete-time ties and zero-length observed intervals (e.g., when a project enters and exits a transient state within the same overarching reporting period). While the Cox model utilized the Efron approximation to handle standard tied survival times, exact zero-length intervals ($T_{stop} \leq T_{start}$) are computationally incompatible with the continuous-time transition intensity frameworks used in competing risks evaluation. To resolve this without deleting valid transition events, a +0.1-year time-jittering was uniformly applied to concurrent transitions. This +0.1-year offset breaks exact ties and ensures computational convergence without biasing duration estimates.

4 SN 4: Natural language processing pipeline for reported reasons of delay

To categorize the justifications reported by promoters for delays and reschedulings, we used a multi-step pipeline combining a lexical baseline, semantic clustering, and expert classification. K-means served only as an exploratory baseline; the thematic grouping used for the final classification was produced by the semantic step.

Data extraction and pre-processing

We extracted the progress-justification text (the “Progress Driver” field), together with the investment identifier and the reported status, from our harmonized longitudinal dataset, and reshaped it into long format (one row per investment and reporting cycle). We then retained the records whose reported progress was flagged as “Delayed” or “Rescheduled” and analyzed the two groups separately, yielding 484 delay statements and 317 rescheduling statements.

Lexical baseline: TF-IDF and K-means

As an initial reference, we vectorized the raw texts with Term Frequency–Inverse Document Frequency (TF-IDF), removing standard English stopwords and restricting the vocabulary to unigrams and bigrams that appear in at least two documents and in no more than 85% of documents. We then ran K-means for K from 2 to 19 (10 initializations per value, fixed random seed) and inspected the inertia curve. The inertia decreased smoothly without a sharp elbow, consistent with the continuous thematic overlap of the justifications; we therefore used K-means only as an exploratory lexical baseline, and not to fix the number of final categories. The solutions inspected as an indicative baseline corresponded to 13 groups for delays and 5 for reschedulings.

Semantic clustering: Sentence Transformers, UMAP, and HDBSCAN

Because justifications with the same meaning are often worded differently (e.g., “permit denied” vs. “authorization stalled”), we complemented the lexical baseline with a semantic representation.

Table 2: Multi-state Cox model of successful phase transitions. Cause-specific hazard ratios (HR) with 95% confidence intervals, estimated with clock-reset (semi-Markov) timing, baseline stratified by phase of origin and environment (onshore/offshore), all covariates interacted with the phase of origin, and robust standard errors clustered on the investment. $HR > 1$ accelerates the transition, $HR < 1$ delays it. $n = 1082$ spells, 462 success events; concordance = 0.716. Reference levels: Extra-EU, Internal, New, Cable/Line, AC, pre-2018.

Driver	Phase	HR (95% CI)	p
Region: EU Member	Consideration	2.58 (1.66–4.01)***	<0.001
	Planning	0.99 (0.57–1.72)	0.978
	Design & Permitting	1.96 (1.18–3.26)**	0.010
	Construction	2.02 (1.26–3.24)**	0.003
Jurisdiction: Cross-border	Consideration	1.80 (1.15–2.80)**	0.010
	Planning	1.10 (0.68–1.76)	0.708
	Design & Permitting	1.24 (0.84–1.82)	0.275
	Construction	1.13 (0.78–1.64)	0.508
Infrastructure: Upgrade	Consideration	0.65 (0.38–1.10)	0.108
	Planning	1.13 (0.66–1.94)	0.650
	Design & Permitting	1.95 (1.16–3.26)*	0.012
	Construction	0.99 (0.64–1.53)	0.969
Element: Nodal	Consideration	0.71 (0.40–1.23)	0.222
	Planning	1.36 (0.79–2.33)	0.265
	Design & Permitting	1.65 (1.00–2.73)	0.050
	Construction	0.80 (0.47–1.37)	0.417
Technology: DC	Consideration	0.36 (0.21–0.63)***	<0.001
	Planning	1.43 (0.86–2.39)	0.168
	Design & Permitting	0.94 (0.44–2.02)	0.879
	Construction	1.15 (0.63–2.11)	0.640
COVID-19 shock	Consideration	0.18 (0.11–0.31)***	<0.001
	Planning	0.15 (0.08–0.29)***	<0.001
	Design & Permitting	0.10 (0.06–0.17)***	<0.001
	Construction	0.34 (0.20–0.59)***	<0.001
New EU reforms (post-2018)	Consideration	3.45 (2.00–5.95)***	<0.001
	Planning	1.91 (1.10–3.32)*	0.021
	Design & Permitting	5.45 (3.10–9.59)***	<0.001
	Construction	2.29 (1.22–4.32)*	0.010

Significance: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, $p < 0.1$.

Each statement was encoded with a pre-trained sentence-transformer model (**all-MiniLM-L6-v2** from the **SentenceTransformers** library) and the embeddings were reduced to two dimensions with UMAP using a cosine metric. We then clustered the reduced embeddings with HDBSCAN using a Euclidean metric, which assigns generic or uninformative statements to a noise category rather than forcing them into a cluster. We grid-searched the UMAP parameters (number of neighbors, minimum distance) and the HDBSCAN parameters (minimum cluster size, cluster-selection epsilon), ranked each configuration by the silhouette score computed on the clustered points (noise excluded), and selected the final configuration from the highest-ranked solutions.

For each resulting cluster we extracted the top TF-IDF keywords and a set of example statements, which we used to interpret the clusters and to define the expert taxonomy applied in the subsequent classification step.

Zero-shot classification (LLM)

Guided by the cluster keywords and example statements, we defined an expert taxonomy of schedule-deviation causes, separately for delays (ten categories, Table 6) and reschedulings (five categories,

Table 3: Robustness model: primary drivers with physical-scale controls (capacity and line length as categories, “Missing” level to avoid listwise deletion; element category omitted as collinear with zero length). Cause-specific hazard ratios for successful transition, 95% CI, robust clustered SE. $n = 1082$, 462 success events; concordance = 0.717.

Driver	Phase	HR (95% CI)	p
Region: EU Member	Consideration	2.70 (1.74–4.17)***	<0.001
	Planning	0.83 (0.48–1.42)	0.501
	Design & Permitting	2.00 (1.19–3.36)**	0.009
	Construction	1.88 (1.16–3.06)*	0.010
Jurisdiction: Cross-border	Consideration	1.94 (1.27–2.97)**	0.002
	Planning	1.01 (0.62–1.62)	0.983
	Design & Permitting	1.09 (0.75–1.60)	0.651
	Construction	1.08 (0.73–1.59)	0.704
Infrastructure: Upgrade	Consideration	0.60 (0.37–0.97)*	0.039
	Planning	1.12 (0.66–1.88)	0.682
	Design & Permitting	2.10 (1.26–3.52)**	0.005
	Construction	0.99 (0.62–1.60)	0.978
Technology: DC	Consideration	0.58 (0.33–1.00)	0.051
	Planning	1.94 (1.12–3.36)*	0.018
	Design & Permitting	1.15 (0.48–2.73)	0.758
	Construction	1.26 (0.62–2.54)	0.523
COVID-19 shock	Consideration	0.12 (0.08–0.19)***	<0.001
	Planning	0.12 (0.07–0.22)***	<0.001
	Design & Permitting	0.08 (0.05–0.12)***	<0.001
	Construction	0.17 (0.09–0.32)***	<0.001
New EU reforms (post-2018)	Consideration	3.26 (2.06–5.15)***	<0.001
	Planning	1.76 (1.02–3.03)*	0.042
	Design & Permitting	5.92 (3.41–10.26)***	<0.001
	Construction	2.79 (1.36–5.70)**	0.005
<i>Physical-scale controls (main effects, not phase-interacted)</i>			
Capacity: Low (ref. High)		1.23 (0.92–1.64)	0.155
Capacity: Missing		1.52 (0.86–2.71)	0.151
Capacity: Zero		1.93 (1.38–2.68)***	<0.001
Length: Missing (ref. Long)		0.32 (0.16–0.65)**	0.001
Length: Short		0.94 (0.73–1.20)	0.599
Length: Zero		0.90 (0.64–1.28)	0.575

Joint tests of the physical-scale terms: likelihood-ratio $\chi^2 = 37.81$, 6 d.f., $p < 0.001$; robust Wald $\chi^2 = 29.21$, 6 d.f., $p < 0.001$. Significance: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, $p < 0.1$.

Table 7), each with a short operational definition. We classified every statement with a locally hosted Llama 3.2 model (Ollama API), supplying the model with the full taxonomy and two worked examples and requiring a single category per statement. Classification followed three fixed rules: assignment by the primary (root-cause) driver rather than downstream consequences; priority of the stated rationale over contradictory boilerplate; and reliance on the underlying driver rather than the promoter’s informal wording. Decoding was deterministic (temperature 0, fixed seed), and outputs that did not contain any valid taxonomy label were flagged as unclassified rather than forced into a category; API failures were flagged separately.

Manual validation and aggregation

Because automated classification can misread long, ambiguous, or internally contradictory promoter statements, we manually reviewed every assignment produced by the LLM against the promoter’s original text, resolving ambiguous cases by the primary chronological trigger. 74 of the delay assignments and 26 of the rescheduling assignments were reassigned. Statements whose text contradicted

Table 4: Coefficient stability of the primary drivers between the main model and the robustness model that adds categorical capacity and line-length controls (with an explicit “Missing” level; $n = 1082$ in both). Geographic and temporal drivers retain sign, magnitude and significance, confirming the institutional effects are not an artefact of omitted physical scale. The technology coefficient attenuates: HVDC assets are systematically longer and higher-capacity, so the scale controls absorb part of the technology effect. Changes are reported on the estimation (log) scale, since differences in raw HR understate movement for hazard ratios below one.

Driver	Phase	HR main	HR robust	$\Delta \log \text{HR}$	% change
Region: EU Member	Consideration	2.58	2.70	+0.04	+4.5%
	Planning	0.99	0.83	-0.18	-16.3%
	Design & Permitting	1.96	2.00	+0.02	+1.9%
	Construction	2.02	1.88	-0.07	-6.9%
Jurisdiction: Cross-border	Consideration	1.80	1.94	+0.08	+8.1%
	Planning	1.10	1.01	-0.09	-8.2%
	Design & Permitting	1.24	1.09	-0.13	-11.8%
	Construction	1.13	1.08	-0.05	-4.9%
Infrastructure: Upgrade	Consideration	0.65	0.60 [†]	-0.08	-7.3%
	Planning	1.13	1.12	-0.01	-1.5%
	Design & Permitting	1.95	2.10	+0.08	+8.0%
	Construction	0.99	0.99	+0.00	+0.2%
Technology: DC	Consideration	0.36	0.58 [†]	+0.46	+58.5%
	Planning	1.43	1.94 [†]	+0.30	+35.6%
	Design & Permitting	0.94	1.15	+0.20	+21.6%
	Construction	1.15	1.26	+0.09	+9.0%
COVID-19 shock	Consideration	0.18	0.12	-0.37	-30.9%
	Planning	0.15	0.12	-0.22	-19.6%
	Design & Permitting	0.10	0.08	-0.30	-25.7%
	Construction	0.34	0.17	-0.68	-49.2%
New EU reforms (post-2018)	Consideration	3.45	3.26	-0.06	-5.6%
	Planning	1.91	1.76	-0.08	-8.0%
	Design & Permitting	5.45	5.92	+0.08	+8.6%
	Construction	2.29	2.79	+0.20	+21.6%

[†]Coefficient crosses the 5% significance threshold between the two specifications. Note that the robustness specification both adds the physical-scale controls and omits element category (collinear with zero line length), so flagged differences cannot be attributed to physical scale alone.

the reported flag—for example, a record flagged as “Delayed” whose justification indicated on-schedule progress—were treated as non-informative rather than as a cause, and flagged records carrying no justification at all (5 delay and 104 rescheduling entries) were placed in the same non-informative category. All percentages are computed over the full set of flagged statements, including the non-informative ones.

The two groups, delays and rescheduling, were analysed at a comparable level of resolution but were not forced onto a single scheme. Reschedulings were classified with a five-category taxonomy and are reported directly at that level (Table 7). Delays used a finer ten-category taxonomy, which we aggregated into six macro-categories (Table 6).

5 SN 5: Classification of cancellation drivers

For the recent planning cycles (2020–2026), where no pre-existing classification of dropped projects was available, we reconstructed cancellation reasons from the official “Non-submitted” and “Non-compliant” lists of the TYNDP Draft Project Portfolios, yielding 51 removed projects. Given the small sample and short text, we used keyword matching and manual validation rather than the embedding-based pipeline used for delays and reschedulings.

Table 5: Proportional-hazards diagnostics (Schoenfeld residuals) for the main and robustness models, and joint tests of the physical-scale terms.

Term	χ^2	df	p
<i>Main model — Schoenfeld PH test</i>			
Region: EU Member	4.25	4	0.37
Jurisdiction: Cross-border	3.50	4	0.48
Infrastructure: Upgrade	5.25	4	0.26
Element: Nodal	1.93	4	0.75
Technology: DC	2.42	4	0.66
COVID-19	3.74	4	0.44
New EU reforms	3.77	4	0.44
Global	29.41	28	0.39
<i>Robustness model — Schoenfeld PH test</i>			
Capacity (categories)	6.70	3	0.08
Length (categories)	4.65	3	0.20
Region: EU Member	4.92	4	0.30
Jurisdiction: Cross-border	4.25	4	0.37
Infrastructure: Upgrade	5.81	4	0.21
Technology: DC	3.22	4	0.52
COVID-19	5.82	4	0.21
New EU reforms	4.57	4	0.33
Global	40.68	30	0.09
<i>Joint tests of physical-scale terms (capacity + length)</i>			
Likelihood-ratio (nested)	37.81	6	<0.001
Robust Wald (clustered)	29.21	6	<0.001

Reviewing the 51 statements yielded seven mutually exclusive categories (Table 8). A keyword script provided a first automatic assignment, and we then reviewed every label against the original text, correcting cases the keyword pass mishandled—for example, “re-clustering” missed because of hyphenation, or an “on hold, internal reasons” entry misrouted by the incidental token “PCI” in an unrelated clause. The manually validated distribution is reported in the main text.

Two points qualify the interpretation. First, for 21.6% of the removed projects no rationale was recorded (“No information” or “Cancelled” without additional details), so their cause cannot be attributed. Second, the reclustering/commissioning category groups projects absorbed into new investment clusters together with a small number already commissioned or close to commissioning; the latter are administrative exits of essentially completed assets rather than failures, consistent with the disaggregation shown in the cancellation case studies.

6 SN 6: 2018 cancellation spike

As illustrated in Figure 4 of the main text, investment cancellations surged significantly during the 2018 TYNDP cycle. Rather than a spontaneous market anomaly, this spike reflects a targeted institutional filtering driven by the transition to more stringent European planning frameworks. We identify three concurrent drivers for this structural break:

- **Methodological tightening (CBA 2.0):** The implementation of the 2nd ENTSO-E Cost-Benefit Analysis (CBA) methodology introduced stricter evaluation criteria for infrastructure projects⁴. Under this revised framework, the projected socio-economic welfare benefits for many early-stage investments dropped substantially, making them impossible to justify to national regulators.
- **Narrowing market spreads:** The 2018 scenario modeling forecasted higher renewable penetration and more uniform gas pricing across Europe compared to previous cycles¹². This projected system optimization reduced the expected price differentials between national markets, thereby eroding the arbitrage-based business case for several cross-border interconnectors.

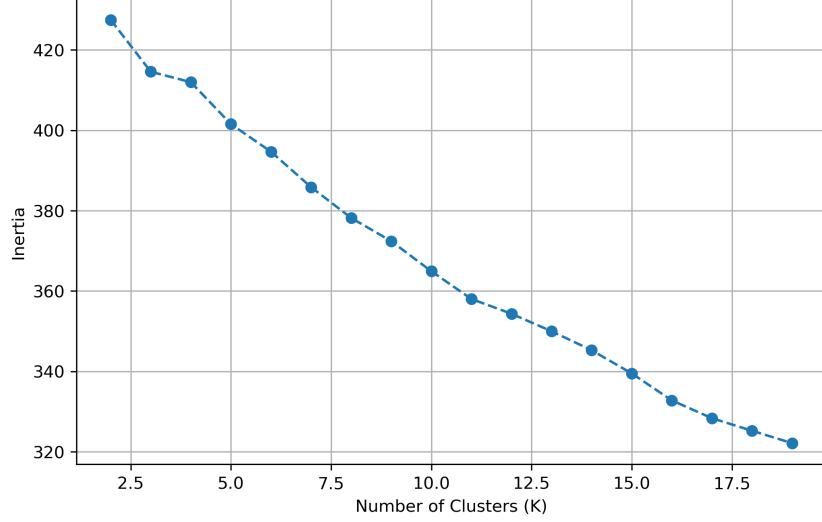


Fig. 1: Inertia (within-cluster sum of squares) of the K-means baseline as a function of the number of clusters K , for the delay justifications. The curve declines smoothly without a sharp elbow, consistent with the continuous thematic overlap of the promoter statements; K-means was therefore used only as an exploratory lexical baseline, and the final thematic grouping was obtained from the density-based semantic clustering.

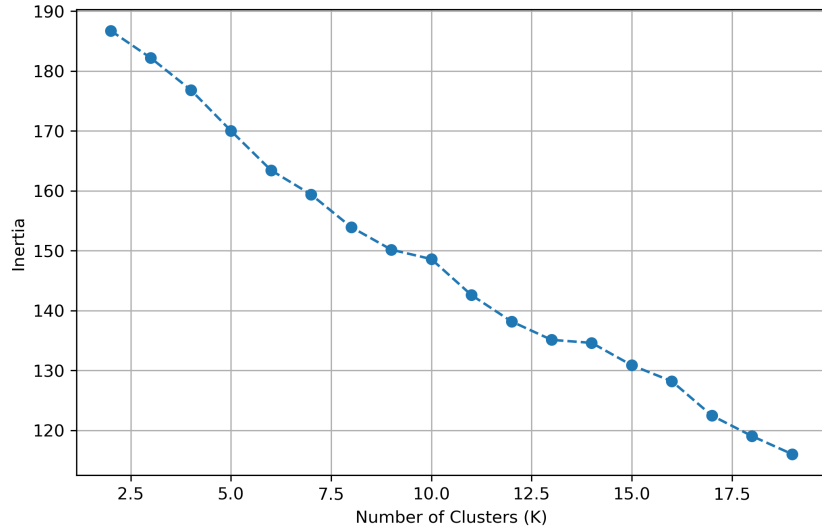


Fig. 2: Inertia (within-cluster sum of squares) of the K-means baseline as a function of the number of clusters K , for the rescheduled justifications. The curve declines smoothly without a sharp elbow, consistent with the continuous thematic overlap of the promoter statements; K-means was therefore used only as an exploratory lexical baseline, and the final thematic grouping was obtained from the density-based semantic clustering.

- **Administrative consolidation:** Faced with the stricter maturity requirements and the burden of the new regulatory era, promoters voluntarily declined to re-submit dozens of stagnant, non-viable concepts, resulting in an automatic administrative sweep.

This dynamic is supported by the broader 2018 policy reforms: the introduction of stricter analytical requirements coincided with a pronounced spike in exclusions, effectively raising the entry barrier for uncommitted or highly speculative proposals.

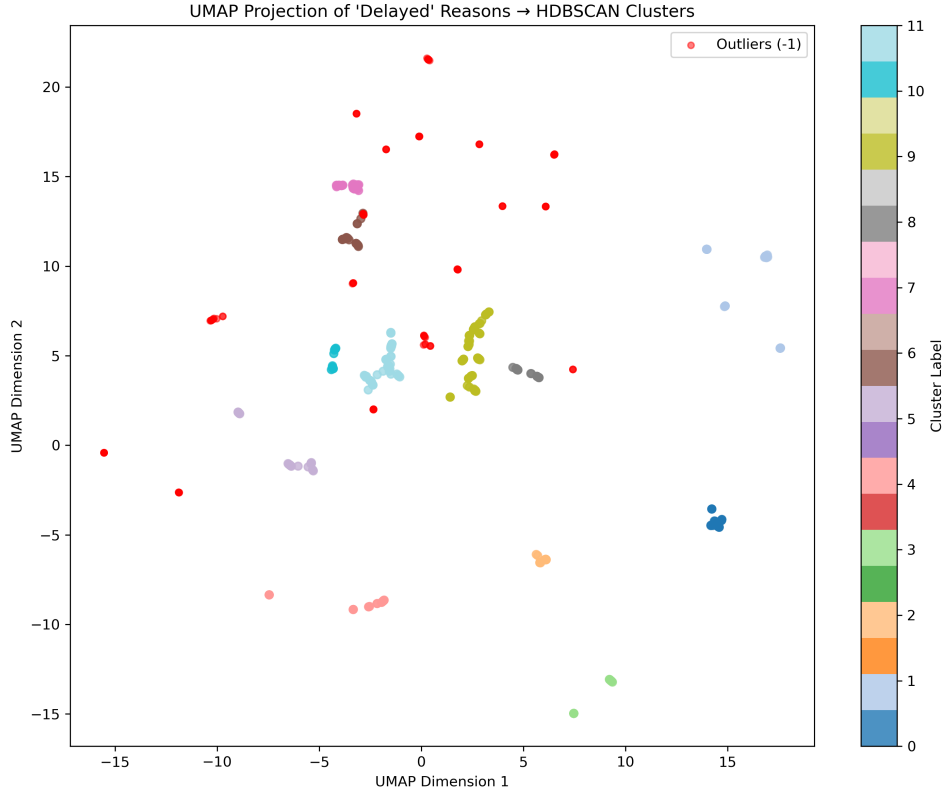


Fig. 3: Two-dimensional UMAP projection of the sentence-transformer embeddings of the delay justifications, coloured by HDBSCAN cluster. The projection is the one used for density-based clustering and is intended to *illustrate* the recovered thematic groups, not to measure their separation: UMAP does not preserve global distances, so inter-cluster gaps and cluster sizes in the plot are not quantitatively meaningful.

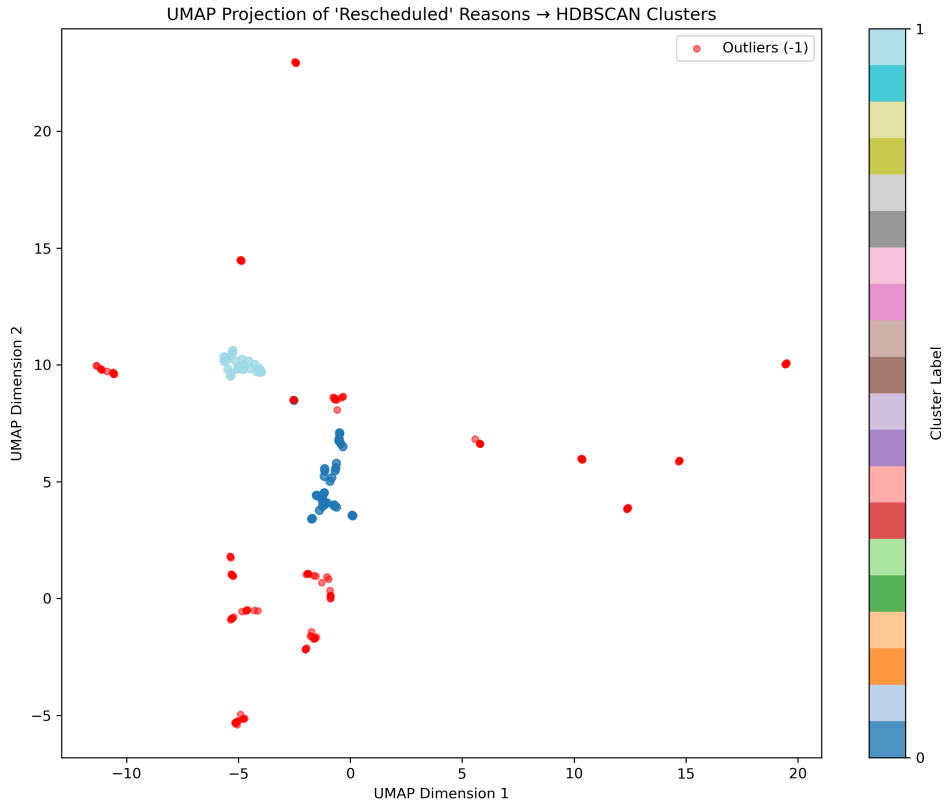


Fig. 4: Two-dimensional UMAP projection of the sentence-transformer embeddings of the rescheduled justifications, coloured by HDBSCAN cluster.

Table 6: Expert taxonomy for the classification of reported **delay** causes. Each statement was assigned to exactly one fine-grained category based on its root-cause driver; fine-grained categories are aggregated into six macro-categories for reporting.

Macro-category	Fine-grained category	Operational definition
Regulatory and permitting	Environmental permitting / EIA	Delays triggered by Environmental Impact Assessments, ecological constraints, or environmentally driven re-routing.
	Legal & regulatory	Delays caused by legislative changes, unclear national frameworks, court rulings, or missing development-plan approvals.
	General bureaucracy	General administrative friction and multi-stage local permitting not classified as environmental or legal.
Technical scope and data	Scope & design changes	Delays from technical/engineering adjustments, feasibility outcomes, or revised planning inputs.
Strategic and systemic interdependencies	Cascading dependencies	Delays caused by exogenous dependencies (correlated grid investments, third-party generation contracts, new plant commissioning).
Social opposition, siting and land acquisition	Social opposition & routing	Delays initiated by local opposition, public resistance, or community-driven re-routing demands.
	Land acquisition	Delays confined to physical or legal expropriation and right-of-way acquisition; excludes broad land-use planning changes.
Lack of information	No delay / data issue	Entries indicating on-schedule progress, or invalid, empty, or uninterpretable text.
Financial and industrial execution	Funding & finance	Delays related to capital procurement, budget deficits, or financial closure; excludes supply-chain contracts.
	Procurement & supply chain	Delays rooted in the industrial supply chain: tendering failures, contractor insolvency, material shortages.

Table 7: Expert taxonomy for the classification of reported **rescheduling** causes.

Category	Operational definition
Strategic and systemic interdependencies	Rescheduling driven by dependencies on other grid elements, alignment with neighbouring lines, demand-scenario shifts, upstream generation changes (RES, nuclear, hydro, offshore), or grid-connection timelines.
Regulatory	Top-down rescheduling from regulatory approvals, CBCA decisions, master-plan updates, intergovernmental agreements, or changes in national/European directives.
Technical scope and data	Rescheduling pending feasibility studies, scope/design changes, novel-solution testing, or contracting/EPC disruptions (e.g. COVID-19).
Siting and land acquisition	Delays related to land acquisition, right-of-way, or physical routing constraints.
Lack of information	Empty entries, hyphens, or statements indicating no substantive change.

7 SN 7: System-wide impact

We quantify the macro-economic cost of the observed failure rates by projecting them onto the project-level benefits reported in the ENTSO-E TYNDP 2024 Cost–Benefit Analysis (CBA). For each project we extract the weighted-average annual benefits at the 2030 and 2040 planning horizons: socio-economic welfare (ΔSEW , M€/yr), avoided CO₂ emissions (ΔCO_2 , kt/yr) and integrated renewable generation (ΔRES , GWh/yr). Benefits for intermediate years are obtained by linear interpolation between the two horizons. Projects without a CBA entry contribute zero to all losses, which biases the totals downward and is consistent with the conservative framing of the estimate. In the CBA

Table 8: Taxonomy of cancellation drivers for projects removed from the TYNDP (2020–2026).

Category	Operational definition
Administrative & compliance failure	Removal for missed submission deadlines, failure to meet mandatory eligibility criteria, or dissolution of the project promoter.
Strategic obsolescence & policy	Loss of strategic rationale, including projects made redundant by updated energy-policy assumptions or by changes in the geographic scope of the framework (e.g. post-Brexit UK-internal or UK–Ireland links).
Reclustering & commissioning	Projects absorbed into new investment clusters, replaced by a successor investment, or already commissioned / close to commissioning.
Permitting & siting roadblocks	Removal driven by permitting refusal or by environmental/social siting constraints.
Withdrawn / on hold	Voluntary withdrawal by the promoter or projects placed on hold for internal reasons.
No rationale provided	“No information”, a bare “Cancelled” flag, or empty entries.
Unclassified	Statements that could not be assigned to any category.

convention, ΔCO_2 is a negative quantity (emissions avoided); forfeiting it therefore adds emissions, and we report the magnitude of the forgone reduction as avoidable CO_2 .

Cancellation losses (2030–2040)

Each project in the 2024 portfolio is assigned a phase-specific cancellation probability derived from the absorbing Markov chain (0.87, 0.70, 0.42 and 0.14 for projects currently under Consideration, Planning, Design & Permitting and Construction, respectively; Fig. 2c). The expected loss of a project is its interpolated annual benefit multiplied by its cancellation probability, accumulated over each year from its planned commissioning date to 2040 (restricted to the 2030–2040 window covered by the CBA).

Delay losses (2030–2040)

For the delay component, we compare each project’s declared commissioning year against an empirically expected year. We calculate this expected year by summing three components: (1) the time the project has already spent in its current phase as of 2024; (2) the expected duration of all remaining phases based on our Markov model estimates (2.2, 3.1, 5.0, and 3.8 years); and (3) a one-year transition allowance. We approximate the time already spent using project statuses across the 2020, 2022, and 2024 portfolios; this conservatively undercounts durations for projects that entered their current phase prior to 2020. We then calculate the delay gap as the difference between the expected and declared commissioning years (floored at zero). Finally, the delay loss is computed by aggregating the project’s interpolated annual benefits over this gap during the 2030–2040 period, capturing the promised welfare and emission benefits that fail to materialize on time.

Substitution and reported ranges

Because part of a cancelled project’s function can be delivered by alternative solutions, cancellation losses are mitigated by a substitution rate before aggregation. We use a central rate of 30%, informed by the share of cancellations whose stated justifications indicate replacement or reduced system need (reclustering 14%; strategic obsolescence, 22%), and report all results under a wide 10–50% sensitivity range, since the share of projects with substitutive justifications is only a proxy for the share of benefits actually substituted. Delay losses are not mitigated, as a delayed project does not trigger a replacement. The headline figures (a cumulative SEW loss of € 158 billion, 488 Mt of avoidable CO_2 and 2,826 TWh of curtailed renewable generation over 2030–2040) correspond to the central scenario; the ranges in the main text correspond to the 50% and 10% substitution bounds.

255 Permanent post-2040 deficit

256 Beyond 2040 the transitional loss becomes a structural one, with two components. First, the expected
 257 annual benefit forgone by projects in the current portfolio that will ultimately be cancelled (2040
 258 benefits weighted by the same phase-specific cancellation probabilities). Second, the benefit of the
 259 28 GW gap that ENTSO-E identifies between the planned portfolio and the optimal 2040 grid topol-
 260 ogy: we convert it using the average benefit density of the 2024 portfolio (total 2040 benefits divided
 261 by total portfolio capacity, ≈ 141 GW). Since transmission projects require an expected 14.1 years to
 262 reach commissioning, capacity not already in advanced planning cannot close this gap by 2040. Both
 263 components are expressed per year and mitigated by the same substitution range, yielding an annual
 264 penalty of roughly €18 billion, 280 TWh and 33 MtCO₂ in the central scenario.

**Table 9: Macroeconomic and environmental losses under different infrastruc-
 ture substitution scenarios.** The central estimate applies a baseline 30% substitution
 rate to the abandoned infrastructure portfolio, reflecting the probability of alternative grid
 solutions being deployed. The lower and upper bounds represent a deliberate sensitivity
 analysis using 50% and 10% substitution rates, respectively.

Metric	High Sub. (50%)	Central Est. (30%)	Low Sub. (10%)
Cumulative 2030–2040			
SEW Loss (€ billion)	130	158	185
Curtailed RES (TWh)	2,386	2,826	3,273
Avoidable Emissions (MtCO ₂ e)	412.2	488.0	564.2
Annual Post-2040			
Structural SEW Penalty (€ bln/yr)	13	18	24
Stranded Clean Energy (TWh/yr)	200	280	360
Sustained Emissions (MtCO ₂ e/yr)	24.1	33.0	43.4

265 8 SN 8: Contextual parallels: anecdotal evidence from the US

266 U.S. transmission projects face similar extended development cycles, showing the European deficit is
 267 not geographically isolated.

268 Historically, US megaprojects spanning multiple states face regulatory gridlock analogous to
 269 the European model. These historical cases exhibit 15- to 20-year development cycles, mirroring
 270 the European TYNDP portfolio, where investments face an expected 14.1-year lifecycle and where
 271 administrative and planning phases consume over 73% of this duration.

272 **SunZia Southwest Transmission Project:** Spanning 550 miles to deliver 3 GW of HVDC
 273 from New Mexico to Arizona, this project was proposed around 2006/2008. It obtained its Record
 274 of Decision from the Bureau of Land Management (BLM) only in 2015. After acquisition by Pat-
 275 tern Energy, modified approvals were secured in 2023, resulting in a 15–17 year cycle to reach the
 276 groundbreaking phase. It became fully operational in 2026¹³.

277 **TransWest Express:** a 732-mile hybrid system comprising a 3,000 MW HVDC segment
 278 (Wyoming–Utah) and 1,500 MW HVAC segments (Utah–Nevada). Initiated in November 2007 with
 279 a preliminary right-of-way application, it required 9 years of environmental reviews to achieve the
 280 initial federal BLM Record of Decision in December 2016. Securing subsequent federal approvals
 281 (WAPA, USFS, BOR), alongside state and county authorizations, extended the permitting phase to
 282 January 2020. The final BLM Notice to Proceed was issued in April 2023, allowing groundbreaking
 283 in September 2023. This represents a 16-year pre-construction cycle driven by compounded federal,
 284 state, and local requirements, with operations targeted for 2031/32¹⁴.

285 **Grain Belt Express:** A 542-mile HVDC line (Phase 1) linking Kansas to Missouri. Initiated
 286 in 2010, the project underwent extensive redesigns and regulatory iterations, securing initial state

approvals between 2013 and 2019 before requiring updated authorizations in 2023. The federal environmental review process commenced in December 2022, culminating in a Final Environmental Impact Statement in July 2025. Despite securing a conditional commitment for a \$4.9 billion federal loan guarantee in November 2024, the Department of Energy terminated the financing in July 2025 due to unmet conditions precedent. This represents a 15-year pre-construction cycle ultimately stalled by compounded financial, technical, and regulatory hurdles¹⁵.

Northern Pass (Cancelled): A proposed 192-mile, 1,090 MW HVDC transmission line linking Quebec to New Hampshire. Initiated in 2010, the \$1.6 billion project faced public opposition over visual and environmental impacts. Despite extensive route redesigns to allow burying 60 miles of the line, and over \$318 million spent on land acquisitions, the New Hampshire Site Evaluation Committee unanimously denied the permit in February 2018. The New Hampshire Supreme Court upheld the rejection in July 2019, officially terminating the project after a 9-year pre-construction struggle, illustrating the systemic attrition driven by social opposition and regulatory roadblocks^{16,17}.

Champlain Hudson Power Express (CHPE) (The Limits of Technical Bypass): A 339-mile, 1,250 MW HVDC line delivering hydropower from Quebec to New York City. Proposed in 2010, promoters opted for a complex engineering solution—burying the cable beneath Lake Champlain and the Hudson River—to bypass visual NIMBY opposition. This strategy successfully expedited the regulatory phase, with the project securing its state Article VII permit in 2013 and its federal Presidential Permit in October 2014. However, groundbreaking did not occur until November 2022. This eight-year stagnation was driven not by fragmented environmental reviews, but by the absence of a viable offtake contract. The project only achieved financial close after securing a renewable energy certificate agreement through NYSEERDA’s Tier 4 program in late 2021. Entering commercial operation in May 2026, CHPE’s 16-year development cycle provides critical evidence that while technical workarounds can resolve permitting friction, they cannot overcome the fundamental commercial hurdle of revenue certainty, ultimately failing to shorten the overarching institutional lifecycle^{18,19}.

The positive example: Centralized Planning.

Texas demonstrates that eliminating governance fragmentation accelerates deployment. ERCOT’s unified regulatory authority and centralized planning bypass cross-jurisdictional friction, delivering large-scale transmission portfolios at a pace unmatched by fragmented systems.

Texas CREZ (Competitive Renewable Energy Zones): A macro-regional plan deploying 3,600 miles of new AC lines. Legislated in 2005, it was fully energized by 2013/2014. Its success relied on a single, centralized authority (the Public Utility Commission of Texas) operating within an isolated interconnection (ERCOT), effectively eliminating federal-state jurisdictional conflicts²⁰.

9 SN 9: Robustness check: cancellation

As noted in the main text, discrepancies between our dataset and official ENTSO-E project statuses primarily arise from our higher granularity. ENTSO-E evaluates progress at the broader “Project” level, which can mask critical pipeline dynamics. Specifically, individual investments frequently disappear from consecutive reports without explanation; by tracking at the investment level, we capture these hidden cancellations.

Frequently, a broader project remains formally active for years, yet its underlying physical configuration changes completely. In many cases, only a small fraction of the initially planned investments survive, significantly decreasing the overall capacity and systemic impact of the project. Granular investment-level tracking is therefore essential.

We acknowledge that, in some instances, investments are merged or reclassified into new investment IDs. While this could theoretically lead to a partial overestimation of “cancellations” in our dataset, we argue that this granular analysis provides the most accurate possible representation of the deployment timeline. Even when a cancelled investment is “merged” or “replaced,” this rarely represents a seamless administrative continuation. Instead, it reflects a fundamental change or reduction in

technical scope, often occurring only after the original physical investment has been blocked by permitting or regulatory issues for over a decade. The original technical option is effectively abandoned, and the “new” investment must often restart the developmental cycle.

Four case studies illustrate these dynamics:

I: Project 124 - NordBalt Phase 2 [Sweden – Lithuania]

This project exemplifies the necessity of investment-level tracking to uncover “lost” planning time and validates our imputation heuristic. In early TYNDP cycles, the internal network reinforcements in Sweden associated with NordBalt Phase 2 were tracked under two macro-investments (IDs 378 and 733). These original investments remained active in the institutional pipeline for nearly a decade without ever reaching construction. Eventually, they were dropped from the TYNDP (in 2020 and 2022, respectively) and replaced by two new, more geographically specific line IDs (1783 and 1784, representing the Nybro-Hemsjö and Ekhyddan-Nybro segments). If analyzed at the overarching Project level, “NordBalt Phase 2” would appear continuously active. However, the investment-level data reveals that the original physical proposals stalled for ten years before being cancelled. In addition, tracking at the investment level allowed our methodology to capture the divergent real-world fates of the two replacement assets:

- **Successful realization (Inv. 1783):** In the 2024 TYNDP, this line advanced to “Under Construction” with an expected commissioning date of December 2026, noting “Permit received.” Because its expected delivery fell within the next reporting cycle ($E_i(y) < y + 2$), our imputation rule correctly classified it as Commissioned when it exited the 2026 database. External verification of Swedish national development plans and construction contracts confirms this asset is currently being built and is slated for operation in 2027^{21–23}. Our model correctly isolated it as a successful completion.
- **Administrative failure (Inv. 1784):** In contrast, the second line was listed as “In Permitting” with institutional roadblocks, explicitly reported as “Permit denied. Appeal process ongoing.” When it was subsequently dropped from the 2026 cycle for being “No longer eligible for PCI/PMI,” our methodology correctly imputed it as Cancelled from the European pipeline.

By avoiding project-level aggregation, our granular approach successfully mapped a decade-long development process: out of four associated investments, three (378, 733, and 1784) either expired or were permanently removed out of the European framework, while only one specific physical asset (1783) successfully reached construction.

II: Project TR 40 [Belgium – Luxembourg – Germany]

The TR 40 Project (Belgium–Luxembourg–Germany) shows how investment-level tracking prevents misclassifying completed projects as failures. The project consisted of three distinct investment IDs, each with a divergent life cycle:

- **Successfully Realized Assets (IDs 446 & 447):** These investments—a Phase Shifting Transformer (PST) at Schiffange and the Heisdorf–Berchem 225 kV loop—were commissioned in 2016 and 2017, respectively. Our methodology correctly classifies these assets as Commissioned based on their life cycle and commissioning dates, capturing their successful integration into the grid.
- **Failed (ID 650):** Conversely, the “long-term perspective” component of the same project (the Aubange–Luxembourg–Germany interconnector) remained in the pipeline as a forward-looking proposal. Unlike the realized assets, this investment failed to progress. In the 2026 cycle, promoters explicitly withdrew the proposal, marking it as “Project has been withdrawn by project promoter” and leaving it out of the new submission list. Our methodology identifies this as a genuine Cancellation, capturing the expiration of an unexercised strategic option.

By disaggregating these IDs, we avoid incorrectly classifying the entire TR 40 project as either a “success” or a “failure.” Instead, we accurately map the reality: the system successfully delivered the

near-term capacity (446 and 447) but failed to convert the long-term expansion (650) into a viable infrastructure project. This confirms that our approach differentiates between the administrative exit of completed assets and the cancellation of the investments.

III: Investment 1048 [Greece – Africa]

The Greece-Africa Power (GAP), Investment 1048, Interconnector highlights regulatory non-compliance as a definitive form of pipeline attrition. It was maintained in the TYNDP portfolio for multiple consecutive cycles (from 2020 to 2024). However, despite its presence in the pipeline, the investment was excluded from the 2026 reporting cycle and flagged as “Non-compliant.”

The justification provided by ENTSO-E stated: “The project did not prove compliance with 2.3.2 criteria. Projects that are partially located outside the ENTSO-E area should connect to the local grid and by this are defined as hybrid offshore projects, having a dual purpose of transmission and generation.” Lacking both this proven hybrid technical structure and the necessary official governmental support required for PCI status, the project was excluded. While a literal interpretation of the database might treat “non-compliant” or “not submitted” records as missing data, our methodology accurately registers this transition as a genuine Cancellation. This reflects the reality of transmission deployment: when a speculative or unsupported option fails to meet evolving regulatory requirements, even after years of active planning, it is permanently eliminated from the European development framework.

IV: Project TR 335 - North Sea Wind Power Hub [Germany – Denmark – Netherlands]

The development of the North Sea Wind Power Hub (NSWPH) reveals how “re-clustering” can mask the complete dissolution of speculative megaprojects, validating the classification of such transitions as cancellations. The NSWPH was proposed as a massive offshore hub-and-spoke infrastructure connecting Denmark, the Netherlands, and Germany. In the 2024 TYNDP, it was tracked as an “Under Consideration” project comprising multiple granular investment IDs (e.g., 1504–1509, 1511, 1815–1819), with an expected commissioning horizon of 2035–2040.

However, in the 2026 TYNDP cycle, all these investment IDs disappeared from the active portfolio. The official justification provided was: “The project was not re-submitted due to re-clustering.” While the overarching “vision” of North Sea integration survived, the specific physical assets proposed under these TYNDP IDs were definitively abandoned. The consortium concluded its conceptual phase, and the capacity targets were conceptually dismantled and absorbed into broader, entirely new Offshore Network Development Plans (ONDPs) and fragmented national initiatives (e.g., individual Danish energy islands).

Treating these disappearances as administrative updates is incorrect, as original investment IDs cannot be mapped to the new ONDP projects. Our methodology correctly classifies these original 12 investment IDs as Cancelled. This accurately reflects the strategic reset of the pipeline: the original physical proposals failed to mature into executable infrastructure, the initial conceptual planning did not yield construction, and the institutional development cycle was restarted under a different planning framework.

10 SN 10: Empirical transition dynamics

Robustness check: addressing left-censoring via funnel cohort analysis

To assess whether the 14.1-year delivery timeline estimated by our Multi-State Markov model is affected by left-censored observations (investments entering the dataset at advanced stages), we conducted a funnel cohort sensitivity analysis. We isolated investments tracked from their inception (Phase 1: Consideration) to successful completion (Phase 5: Commissioned).

Out of over 900 tracked investments, 117 entered the pipeline at Phase 1. Given the high attrition rate and the 16-year observational window of our dataset (2010–2026), only 7 of these investments completed all four developmental phases. The raw cumulative duration for this cohort is 11.8 years. Because the dataset spans a 16-year period, investments requiring more time to complete the cycle are excluded from this count due to right-censoring. Consequently, this 11.8-year average represents a lower bound influenced by survival bias, capturing only the fastest projects. The observation that this selected cohort requires nearly 12 years to reach commissioning suggests that the 14.1-year Markov chain projection is not biased upward. Rather, it accounts for delays and long-tail overruns that simple raw averages fail to capture.

We additionally analyzed a secondary cohort of investments tracked from Phase 2 (Planning). Within this group, 23 investments reached commissioning, requiring an average of 10.12 years to complete the remaining developmental stages. Accounting for the average duration of the initial Consideration phase, the total lifecycle for this cohort is approximately 12.7 years. These robustness checks confirm that deployment timelines are protracted, supporting the 14.1-year expectation derived from the multi-state model. Table 10 summarizes the phase-specific durations and attrition for both cohorts.

Table 10: Funnel Cohort Analysis: Phase-specific mean durations and surviving sample size for investments tracked from Phase 1 and Phase 2.

Phase Transition	Cohort 1 (From Phase 1)		Cohort 2 (From Phase 2)	
	Duration (y)	N	Duration (y)	N
1 → 2 (Consideration → Planned)	2.60	117	–	–
2 → 3 (Planned → Permitting)	2.56	32	3.20	107
3 → 4 (Permitting → Construction)	4.33	12	3.88	41
4 → 5 (Construction → Commissioned)	2.29	7	3.04	23
Cumulative Duration	11.78	7	10.12*	23

*Note: Cumulative duration for Cohort 2 excludes Phase 1.

Case study: forward jumps and project re-scoping (Project 1104; Roost – Flebour)

A representative example of these non-linear transitions is the cross-border reinforcement between Luxembourg and Germany (TYNDP ID 1104). In the TYNDP 2022, this investment was forecasted for commissioning in 2027, implying a major reconstruction effort. However, the subsequent TYNDP 2024 reported the project as already commissioned in 2022, creating a data artifact suggesting a sudden five-year acceleration.

Source verification against the national TSO planning documents clarifies this discrepancy. The *Creos Luxembourg Network Development Plan 2024-2034* confirms that the project strategy shifted from a potential line reconstruction to a reconductoring intervention using High Temperature Low Sag (HTLS) technology. As stated in the national plan: “the overhead lines between the country border near Vianden and the station Flebour, as well as between the stations Flebour and Roost, have been recently upgraded with high-performance conductors (HTLS)”¹. Since this represents a brownfield optimization rather than the greenfield construction of a new line, such data artifacts must be contextualized to prevent distortion of the lead-time analysis. Including these outliers in simple averages would artificially deflate the expected duration. This underscores the necessity of our Markov chain framework, which accounts for these reporting anomalies—capturing them as discrete “forward jumps” (Table 11)—and prevents project re-scoping from skewing the systemic timeline.

¹Reference: Creos NDP, page 25. Available at: <https://www.creos-net.lu/en/individuals/creos-luxembourg/ndp>

Table 11: Summary of all observed state transitions (2010–2026) (Note: Shaded rows represent non-linear transitions, including forward jumps, backward steps, or resumptions. Total Success Path Transitions: 512; Total Cancellations: 443; Transitions Backwards:64; Jumps ahead: 66)

Transition	Path Type	Mean Duration (Years)	Sample Size (N)
1 → 2	Progress (Consideration to Planning)	2.60	117
1 → 3	Forward Jump	2.77	13
1 → 4	Forward Jump	2.67	3
1 → 5	Forward Jump	3.00	2
1 → 6	Cancellation	3.29	235
2 → 1	Backward Step	2.45	31
2 → 3	Progress (Planning to Permitting)	3.20	107
2 → 4	Forward Jump	3.06	17
2 → 5	Direct Completion	3.60	5
2 → 6	Cancellation	3.19	118
3 → 1	Backward Step	3.87	15
3 → 2	Backward Step	2.73	11
3 → 4	Progress (Permitting to Construction)	4.17	142
3 → 5	Direct Completion	5.62	26
3 → 6	Cancellation	4.08	71
4 → 2	Backward Step	1.00	2
4 → 3	Backward Step	1.20	5
4 → 5	Progress (Construction to Commissioning)	3.09	146
4 → 6	Cancellation	2.38	19

11 SN 11: Robustness check: linear regression on delay magnitude

To test whether the magnitude of delays could be predicted from available project characteristics, we conducted a robustness check using an Ordinary Least Squares (OLS) regression.

The dependent variable was defined as the log-transformed standardized delay (years of delay accumulated per reporting cycle). To satisfy the assumptions of the log-linear model, the sample was restricted to investments experiencing positive delays ($n = 398$). Independent variables included jurisdictional scope (Internal vs. Cross-border), geographic region (EU vs. Extra-EU), infrastructure type (New vs. Upgrade), technology (AC vs. DC), and element category (Nodal vs. Cable/Line). To prevent overfitting, individual country fixed effects were excluded due to the low number of observations for several nations. Continuous physical metrics (capacity in MW and line length in km) were transformed into categorical bins (e.g., Short, Medium, Long, and Missing). This transformation prevented sample attrition from missing data and avoided structural distortions, such as improperly imputing 0 km to missing line lengths or confusing them with nodal infrastructure.

We assessed multicollinearity among the predictors using the Variance Inflation Factor (VIF). Variables exhibiting perfect collinearity (e.g., overlapping “Unknown” categories) were removed from the specification. All retained features in the final model demonstrated a $VIF < 7$, confirming a stable design matrix free from multicollinearity.

The OLS regression yields an Adjusted R^2 of 0.074 (F -statistic = 3.250, $P < 0.001$) table 12. This low explanatory power supports the main argument: technical specifications and physical scale account for a marginal fraction of schedule overruns. Instead, the magnitude of these delays is driven primarily by early-stage coordination failures rather than technical complexity. Notably, the model reveals that the construction of linear assets (classified as Short, Medium, or Long lines) is associated with a statistically significant increase in delay magnitude ($P < 0.05$) compared to the baseline of nodal infrastructure (0 km). However, beyond the initial penalty of being a linear asset, the specific

length of the line, its capacity class, and the specific technology deployed (AC vs. DC) show no statistically significant correlation with the severity of the delay.

Table 12: OLS Regression results for the magnitude of schedule overruns (log-transformed standardized delay).

Variable	Coef.	Std. Err.	$P > t $
<i>Intercept</i>	-0.707	0.238	0.003
Project Jurisdiction: Internal	-0.055	0.085	0.640
Project Region: Extra-EU	0.114	0.088	0.197
Nodal Infrastructure	0.270	0.167	0.106
Technology (AC-DC): DC	0.028	0.127	0.829
<i>Length Class</i>			
Short ($< 50km$)	0.432	0.201	0.032
Medium (50-150km)	0.441	0.205	0.032
Long ($> 150km$)	0.498	0.213	0.020
Missing	0.549	0.238	0.021
<i>Capacity Class</i>			
low ($< 500MW$)	-0.171	0.148	0.247
Medium (500-1500MW)	-0.070	0.139	0.615
Missing	0.394	0.218	0.071
New Infrastructure	-0.004	0.107	0.974
<i>Adjusted R-squared: 0.074 Observations: 398</i>			

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