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Mind the Queue:

Connection Reform for the Electricity Grid

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Objective

1 Illustrate the **importance of grid connection reforms** to debottleneck energy transition and industrialization goals

2 Introduce the **option space of levers**, and examples of markets where we have seen them being implemented

3 Provide **recommendations to grid operators** on how to move forward with reforming grid connection processes

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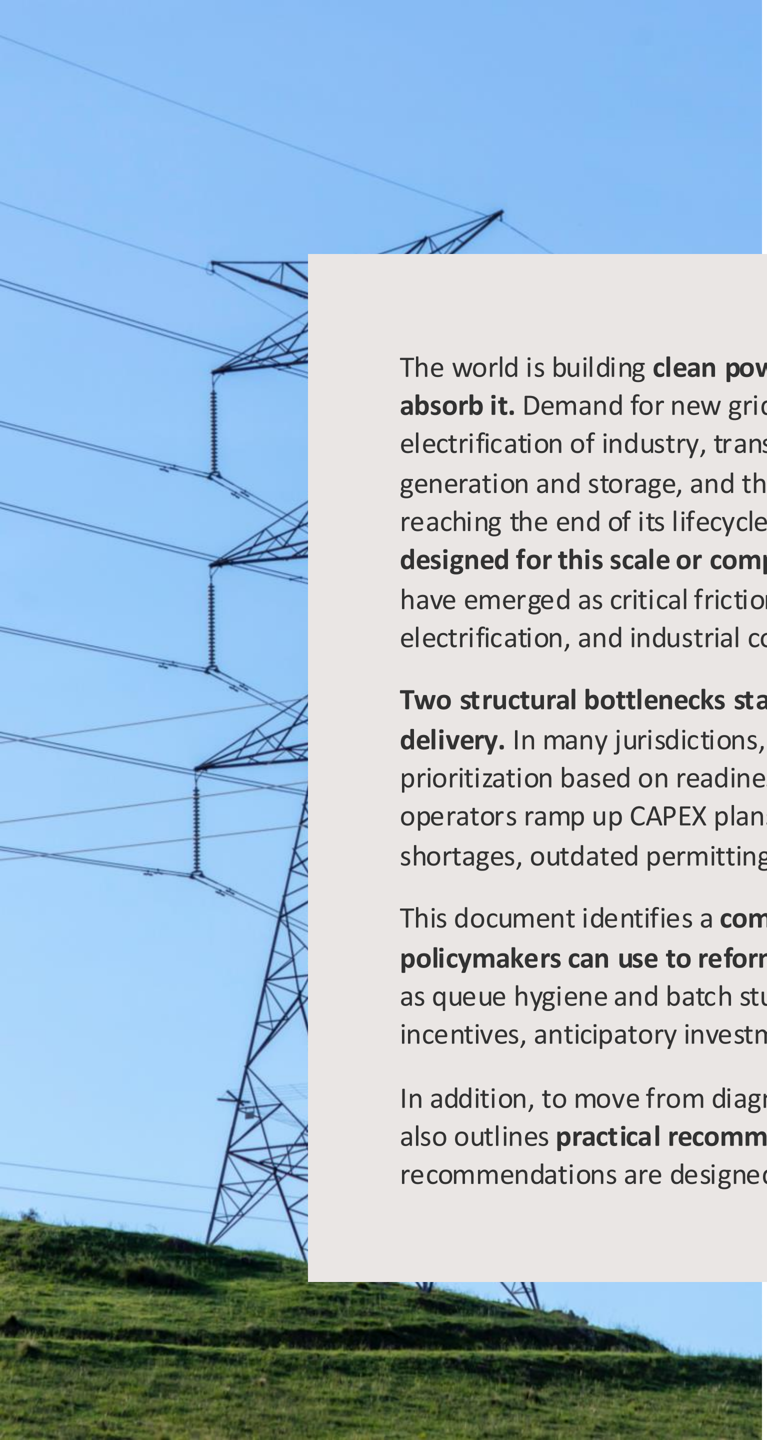


Preface

The world is building **clean power and electricity offtake faster than grids can absorb it.** Demand for new grid connections is accelerating—driven by the electrification of industry, transport, and heating, the rapid build-out of renewable generation and storage, and the need to replace aging grid infrastructure that is reaching the end of its lifecycle. Yet, **many grid connection processes were not designed for this scale or complexity**. As a result, long queues and delivery delays have emerged as critical friction points, limiting progress on decarbonization, electrification, and industrial competitiveness.

Two structural bottlenecks stand out: connection studies and physical grid delivery. In many jurisdictions, studies are still processed sequentially, with limited prioritization based on readiness or system value. Meanwhile, even as grid operators ramp up CAPEX plans, infrastructure delivery is being slowed by resource shortages, outdated permitting frameworks, and fragmented supply chains.

This document identifies a **comprehensive set of levers that grid operators and policymakers can use to reform connection processes**, ranging from measures such as queue hygiene and batch studies to flexible connections, targeted locational incentives, anticipatory investments, and new market-based allocation mechanisms.

In addition, to move from diagnosis and lever-longlisting to action, this document also outlines **practical recommendations for grid operators.** These recommendations are designed to **help prioritize and sequence reform efforts.**

While some grid operators are moving toward more integrated reforms, deploying multiple levers in tandem, this remains the exception. Even in these cases, the effectiveness of such holistic packages is still being tested in practice. Many other jurisdictions continue to rely on piecemeal or ad-hoc approaches, and some have yet to act at all. To truly debottleneck the transition, grid operators must consider the full suite of tools and tailor coordinated, high-impact reform strategies that fit their context and broader market design philosophy. In addition, **we also provide recommendations for markets that have not yet encountered large queues**, offering a chance to adopt preventative measures before congestion sets in.

The **cost of inaction is clear**. Industrial customers face electrification delays and a loss of global competitiveness. Renewable energy, data center, and utility-scale battery project developers risk stranded capital or are being pushed to reconsider project locations or defer timelines. Regulators and the public sector face mounting pressure as grid constraints threaten broader energy transition, economic, and policy goals. Grid operators are under growing operational strain, facing delivery backlogs and reputational risks in an environment that is increasingly visible, politicized, and high-stakes.

Grid connection reform is a foundational enabler of the energy transition. **The time to act holistically, and with urgency, is now.**

Power systems are in full transformation, with these changes translating into a large set of new offtake and injection points requesting grid connection

Global electricity demand expected to rise by 25-30% from 2023 to 2030

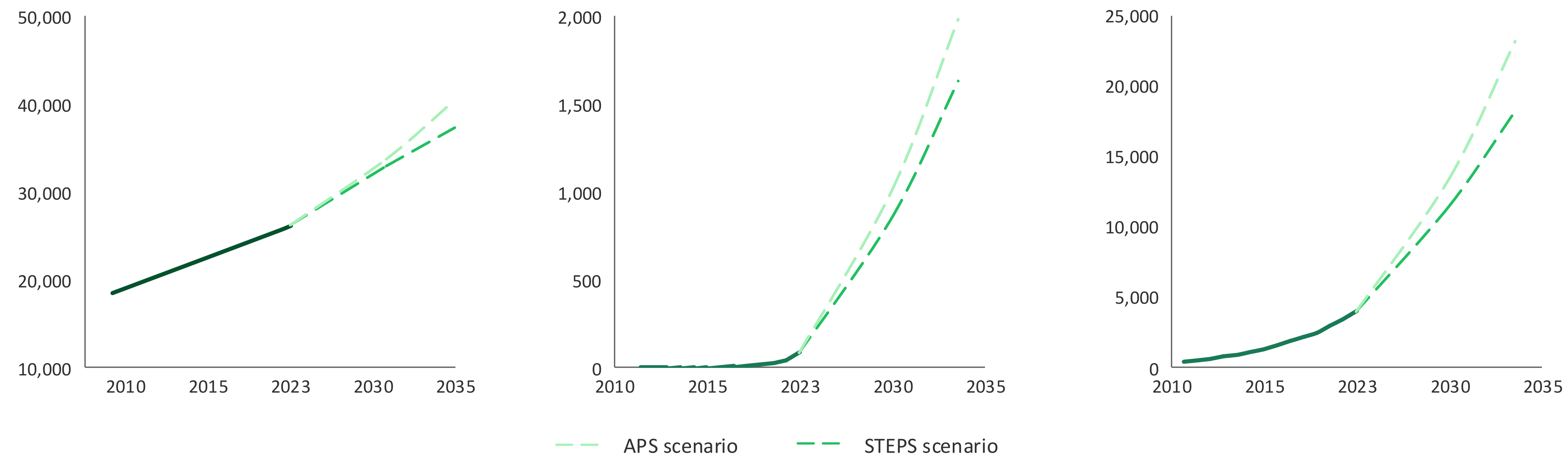
Global electricity demand in TWh

Battery storage expected to grow at a CAGR of 35-45% through 2030

Battery storage in GW

Solar & wind expected to grow at a CAGR of 15-20% through 2030

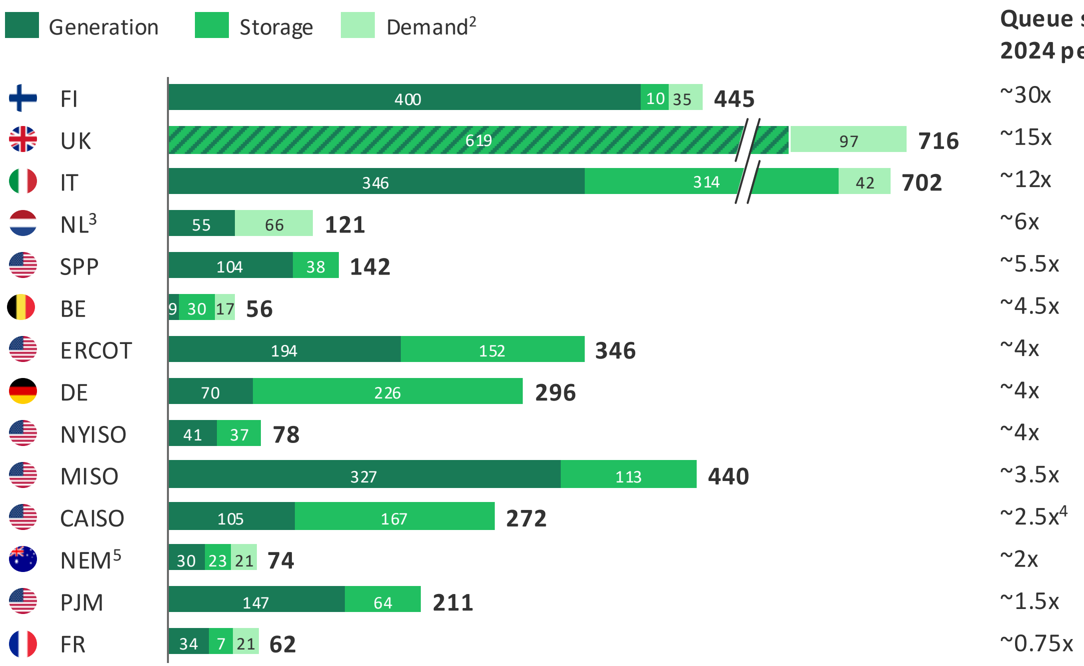
Global solar and wind generation in TWh



Note: STEPS = "Stated Policies Scenario" (outlook based on today's enacted policies), APS = "Announced Pledges Scenario" (outlook assuming all government pledges are met), CAGR = Compound Annual Growth Rate
Source: Ember, Yearly Electricity Data; IEA World Energy Outlook 2024 (includes actuals up until 2023, and forecasts as of 2024); BCG analysis

However, large queue sizes and long lead times delay new grid connections

Queue sizes (GW)[1]



Lead times (Years)

"In the US, the typical duration from connection request to commercial operation increased from <2 years for projects built in 2000-2007 to over 4 years for those built in 2018-2023 (with a median of 5 years for 2023)"
- Berkeley Lab (2024)

"Over the last 5 years the volume of connection applications to the transmission network has grown approximately tenfold. This has led to an average delay of over 5 years for UK projects"
- Ofgem (2023)

"The Netherlands faces up to 10-year wait times for new data center connections, the longest among surveyed jurisdictions"
- PPC Land (2025)

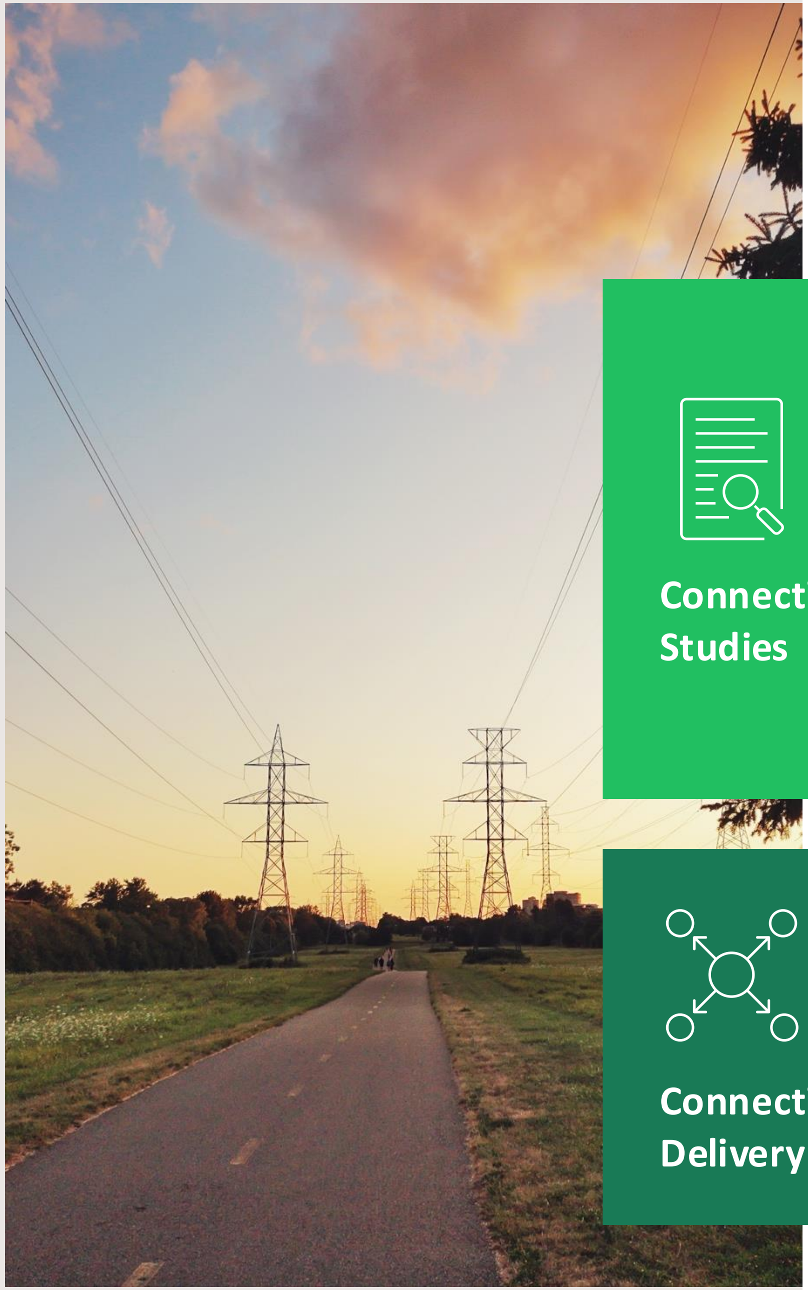
"New data centers in Germany wait an average of up to 7 years for a grid connection"
- German Data Center Association (2025)

1. Queue size for the transmission grid (distribution grid connection queues are also significant in most markets), with "queue" containing everything that is at the stage of connection inquiry / initial grid study up to physical connection delivery, hence also including projects that have highly uncertain business cases and may never be realized 2. Demand-side parts of the interconnection queues, which are estimated to be in the hundreds of GW already alone for data center projects in the US, are not included in the US data as they are (generally) managed by utilities 3. 70 GW of (battery) storage is included in the data for Generation and Demand 4. Queue size vs 5' peak load 5. Combined transmission and distribution queue size due to data availability for generation and storage, while for demand it only represents the transmission-level queue; Source: Queue size: US: Berkeley Lab (2024); UK: ENA Connections Databook (2025); FI: Euronews (2025), Fingrid (2024); IT: Terna (2025), Reuters (2025); NL: Netbeheerder NL (2025), PV magazine (2025); BE: Elia (2025), DE: CleanEnergyWire (2025), Euronews (2025); NEM: AEMO Connections Scorecard (Q2 2025); for the demand-side queue sources incl. Transgrid, Ausnet, Electranet, no demand-side queue data included for Tasmania and Queensland; FR: StatInfo Energie (2025), CDE (2025), RTE (2025); Peak hourly load (2024): ENTSO-E; CREG; AEMO; NESO; Regional US authority websites and reports; BCG analysis

Significant cost of inaction when actors fail to perform grid connection reforms

	Industrials	Project developers	Regulators and Public sector	Grid operators
Pain point	• Electrification projects stall, potentially forcing industrials to defer or cancel investments • Power prices rise, threatening regional competitiveness and jobs	• Capital sits idle for years, impacting returns • Large delays push developers to less congested regions	• National climate and industrialization goals risk slipping • Public and political pressure mounts as policy targets are missed	• Operational overload put pressure on internal teams and processes • Reputation takes a hit as industrials and politicians blame the grid and its operators for lost growth
Example	Close to 12,000 Dutch businesses are on the grid waiting list; leading tech cluster in Eindhoven warns that lack of capacity is blocking new investments	Average interconnection wait time in the US has risen 70% since 2010; and about 78% of queued projects withdraw before construction, resulting in lost effort and capital	UK regulator Ofgem labels grid delays the biggest risk to decarbonizing the power system	PJM Interconnection froze new grid connection requests for 2023-2025 to clear its 250+ GW backlog. The pause defers roughly $3B of network upgrade spending by 3-4 years

Source: Financial Times (13 Jul 2025); Lawrence Berkeley Lab "Queued Up" (May 2025); Ofgem Connections Action Plan (22 Nov 2023); Utility Dive (16 March 2023); BCG analysis



Two types of connection bottlenecks are causing this:

1. Connection Studies and 2. Connection Delivery

1

Connection Studies

1.1 Backlog in grid connection studies

When grid users request a new connection, grid operators perform simulations on what is possible, as well as when and where

1.2 First-come first-serve not leading to optimal outcomes

In many markets, historically, in a world with less connection requests, a ”first come first served” principle was applied

1.3 Inflated queues driven by speculative or duplicative requests

In many markets, a significant share of connection requests are speculative, duplicative, or unrealistic. These distort the true size of the connection queue

2

Connection Delivery

2.1 Increasing lead times for the physical delivery of connections

Grid operators are massively scaling up their CAPEX plans, but delivery models and supply chains are not keeping pace

2.2 Insufficient available grid capacity to accommodate all requests

In several regions, current and planned grid infrastructure is proving insufficient to accommodate requests in the queue, requiring even more backbone upgrades

Source: BCG analysis

Queues are new to the grid, but not new to life:
lessons learned from the airline industry

1. Entry to aircraft by boarding group
2. Passengers with pre-check-in allowed to skip the queue
3. Different security lanes for families, business travelers, and crew
4. Passengers trading tickets with those willing to pay in case of overbooking
5. Families and disabled people boarding first
6. Airlines bidding for scarce runway slots, with highest-paying winning
7. Passengers without boarding passes asked to leave the line
8. Automated passport gates to speed up passenger processing
9. More efficient processes for crew-specific security line
10. Ticket classes with known conditions: Economy, Business, First
11. If the plane is not ready to depart, take-off slot lost
12. Incentives for airlines to operate from less busy terminals
13. Faster turnaround through shorter time between take-offs/landings
14. Fast track passengers with short connection at security
15. Private operators adding check-in desks beyond airport authority
16. Extra security lines to be added before the holidays
17. Early-morning or late-night flights to ease pressure on peaks

Resolving Bottleneck #1: Connection Studies | Nine levers to mitigate the connection study bottleneck, across queue management and queue efficiency

Lever group	Lever	Description	Airline industry analogy
Queue management levers	**Batch study processing**	Connection requests grouped into coordinated batches, typically by region and submission window, and studied jointly to streamline network planning, optimize reinforcement needs, and reduce duplication vs. sequential, project-by-project reviews	Entry to aircraft by boarding group
Queue management levers	**First-ready, first-served**	Only projects that have a certain maturity (e.g., with permits and financing) get prioritized, helping to speed up the development of "real" projects	Passengers with pre-check-in allowed to skip the queue
Queue management levers	**Segments per project type**	Grid capacity pre-divided across project types (e.g., industry, renewable generation, data centers) to ensure balance across the energy system	Different security lanes for families, business travelers, and crew
Queue management levers	**Queue tradability**	Enable trading of queue positions so access flows to the most ready or highest willingness-to-pay projects. A missing market today, and potentially a frontier idea, but one that requires safeguards and new regulation	Passengers trading tickets with those willing to pay in case of overbooking
Queue management levers	**Value-based prioritization**	Projects ranked based on how much they support pre-defined goals, like reducing emissions or contributing to industrial growth/ competitiveness, or any other policy goal	Families and disabled people boarding first
Queue management levers	**Market-based allocation**	Developers compete for grid access through auctions or tenders, with the projects that are most cost-effective, or have the highest willingness-to-pay, win the right to connect to the grid	Airlines bidding for scarce runway slots, with highest-paying winning
Queue efficiency levers	**Queue hygiene measures**	Inactive or speculative projects removed from the queue based on milestones (e.g., permitting, financing), with periodic reviews to keep queue credible	Passengers without boarding passes asked to leave the line
Queue efficiency levers	**Increased study throughput**	Increase study throughput by ramping up resources, streamlining the study process (e.g., standardized methods, adapted granularity, use of automation), or reinventing it by using (gen)AI and digital twins	Automated passport gates to speed up passenger processing
Queue efficiency levers	**Faster path for certain assets**	Fast-track studies for specific assets (e.g., storage), treated differently from generators or load, recognizing their unique system value and benefit to grid operations	More efficient processes for crew-specific security lines

Source: BCG analysis

Resolving Bottleneck #1: Connection Studies | Multiple examples of grid operators implementing them

Queue management levers

Batch study processing

"Open season" windows only in highly saturated grid areas: connection requests are collected over 3 months and jointly assessed post-window; in addition, the country is split into 76 microzones, evaluated in location-based batches
– implemented in 2025

Enduring Connection Policy processing grid applications in batches, with single annual application window until 2024, now shifted to bi-annual batch windows
– implemented in 2018, reviewed in 2024

First-ready, first-served

"First Ready and Needed, First Connected": Under the approved TMO4+ reforms, projects that demonstrate readiness (e.g., secured land rights, and planning consent progress) will leapfrog others
– to be implemented in 2025

Midcontinent ISO's interconnection process embodies a first-ready approach as part of its cluster studies; projects must meet strict readiness milestones (e.g. site control, higher deposits) to enter phases
– implemented in 2017

Segments per project type

NESO introduced a special queue segment for battery storage in 2023 as part of a "five-point plan." Storage projects can connect faster by bypassing certain enabling works and accessing non-firm arrangements
– implemented in 2023

In Germany, renewable energy projects have priority connection status by law, with operators to expedite renewable generation connections, effectively ranking renewable generators ahead of conventional plants for access
– implemented in 2000

Queue tradability

The idea that access rights can be treated as a tradable asset is not yet mainstream in policymakers or TSOs, but represents a potential next frontier. To our knowledge, no grid operator has yet officially implemented tradable queue models, but market sources claim that in some geographies queue slots are (or could be) traded bilaterally already today (with consent)

Value-based prioritization

Dutch regulator allows grid operators to grant priority "fast lanes" for projects with exceptional societal or strategic value
– currently not (yet) implemented, being reviewed by 2026[1]

Projects screened against Readiness and Strategic Alignment criteria; NESO runs the process, while Ofgem provides regulatory oversight. Strategic alignment considers system value, e.g. net zero contribution, technology mix, or supporting government priorities
– expected to be implemented in 2025

Market-based allocation

Spain's Royal Decree enables connection capacity tenders at certain nodes of the transmission grid; When capacity is freed up (or a new node is built), the government solicits bids for those slots with award based on a multi-criteria basis (bid timing, socio-economic and environmental benefits, technology mix, etc.)
– implemented in 2020

Developers competitively bid for guaranteed access capacity in pre-defined zones in Australia's South West REZ (New South Wales)
– bid organized in 2024

Queue efficiency levers

Queue hygiene measures

ERCOT's Milestone Tracker clears inactive projects by enforcing strict progress checks: projects not meeting deadlines for land rights, permits, or interconnection studies are automatically removed from the queue
– implemented in 2023

Ofgem raised the TIA threshold in England & Wales from 1 to 5 MW to accelerate distribution-scale projects by reducing number of small projects requiring detailed transmission studies
– decided in May 2025

Increased study throughput

PJM overhauled the interconnection process and hired more staff to clear backlog, cutting pending queue from ~200 GW to ~67 GW
– implemented in 2022/23

PJM partnered with Google AI (Tapestry) to automate study data processing and modeling for faster approvals
– implemented in 2025

MISO introduced automation tools (with Pearl Street Tech) for studies and set annual queue caps; goal to cut study timeline to ~1 year
– implemented in 2025

Faster path for certain assets

Australian Energy Market Commission's IESS reforms created a separate participation category for storage and hybrids, with specific study/assessment needs, bespoke tariffs and negotiated connection agreements
– implemented in 2021 and 2023

1. Court struck down ACM's prioritization framework due to insufficient legal basis and omission of key societal services (e.g., telecom). ACM must re-assess and re-justify criteria by 2026
Note: TSO = Transmission System Operator, ISO = Independent System Operator, NESO = National Energy System Operator, Ofgem = Office of Gas and Electricity Markets, IESS = Integrating Energy Storage System, TIA = Transmission Impact Assessment, AEMC = Australian Energy Market Commission, REZ = Renewable Energy Zone, ACM = Authority for Consumers and Markets (Netherlands), TMO4 = Transmission Modernization Order 4 (UK); Source: BCG analysis

Zoom—Queue tradability | The next frontier or doomed to be prohibited?

Benefits

- Faster grid access for shovel-ready projects
- Delayed or cancelled projects can recover costs and reinvest in viable ones
- "Zombie" projects are more likely to exit pro-actively if they can sell their slot
- Trading allows for price discovery and shows where early grid access is most valuable, helping to prioritize local upgrades

Challenges

- Speculators may book grid slots just to hold and resell them for profit
- Early access might go to the highest bidder, not the most-ready or most-valuable project from a societal perspective
- Higher costs could be passed to consumers
- Increased complexity for grid operators, in case of different grid-interacting behavior of the new owner (potentially triggering new grid studies)

Position towards queue tradability in selected markets, currently mostly not allowed

✕ Prohibited

Market	Tradability
UK	✕
USA	✕ *Exception for mergers only*
NEM	✕ *Only with AEMO consent*
ES	✕
IE	✕ *Only with CRU consent*
NL, DE, DK	≈ No formal market, but some jurisdictions allow for a transfer in case of regulator / grid operator approval

Conclusion

Although restricted for now, queue tradability offers clear benefits: it helps shovel-ready projects connect sooner, frees up grid space, and reveals where access is most valuable. It can in theory work well, but only with safeguards to avoid gaming or unfair access:

- **Milestone requirements**, to prevent slot hoarding
- **Transfer restrictions**, to avoid pure speculation
- **Operator oversight**, to manage fairness and disputes
- **Technology alignment**, to ensure transfers involve similar grid-interacting assets, avoiding the need for new studies

Note: FERC: a company may keep its queue position if it is acquired or merges with another entity, without needing to reapply; CRU = Commission for Regulation of Utilities
Source: NESO CMP435 draft (Jan 2025); FERC Order No. 2023 (Jul 2023) + PJM, MISO, CAISO tariffs; AEMO CRI Roadmap (May 2023); Royal Decree 1183/2020 (Spain); CRU Consultation CRU /24/028 (Feb 2024); Energinet connection terms (2019); BCG analysis

Resolving Bottleneck #2: Connection Delivery | Eight levers to mitigate the connection delivery bottleneck, across commercial and infrastructure

Commercial levers

Tiered connections

Also known as "flexible connections". Opportunity for projects to connect sooner by accepting ramped, interruptible or time-restricted access (e.g., during peak demand times, high solar generation, overnight) for both new and existing grid users; options vary based on curtailment duration/notice and whether the solution is temporary or permanent

Scrutiny on contracted capacity

Check use of contracted capacity of current grid users, and if un-used (or not needed within a certain timeframe), it must be returned ("use-it-or-lose-it"). If users need that headroom in a number of years then it might be temporarily used to enable another connection (but introduces a "CAPEX delivery commitment" for the TSO)

Location steering through signals

Steer customers to areas with available grid capacity (e.g., data centers close to the coast in case of offshore wind), either through "soft" signals such as publishing capacity hosting maps or differentiated connection times per zone, or through more formal signals such as differentiated grid fees, dedicated data center, RES, or battery zones with superior connection speeds, or even locational or zonal pricing reforms

Infrastructure levers

Getting more out of existing assets

Adjust historical operational/risk thresholds, especially in non-critical or easy-to-replace assets, accepting potentially reduced asset lifespan or higher asset failure risk in exchange for faster connections. Performing such practices not only on the transmission level, but also on the distribution level, can help free up additional transmission capacity

CAPEX project acceleration

Fast-track permitting as a mission-critical item, review current delivery models (e.g., use of contractors vs. in-house, optimization of the stage-gate process), ramp up resources, and engage strategically with the supply chain to avoid bottlenecks. Our project experience shows there is up to 20-50% acceleration potential for new projects

Independent connection delivery

Enable third parties to deliver grid connections or support self-build options for customers at pre-identified connection points. This approach can speed up connections, by expanding delivery capacity beyond the grid operator's capacity, but requires changes in regulation related to regulatory quality standards and activity perimeters

Anticipatory investments

Design and build infrastructure with excess capacity upfront in areas of strategic interest to accommodate future grid users. However, this might make the CAPEX delivery constraint initially worse before making it better, and might raise affordability questions for grid users in case that headroom is never used (risk of stranded assets)

Flexible asset deployment

Directly use flexible assets at congested areas of the grid, or incentivize market participants to invest in those front-of-the-meter flexibility assets or in behind-the-meter flexibility assets—such as batteries and smart EV chargers—to flatten peak use of the grid. These assets can help free up capacity and ease pressure on constrained parts of the network

Airline industry analogy

Lever	Airline industry analogy
Tiered connections	Ticket classes with known conditions: Economy, Business, First
Scrutiny on contracted capacity	If the plane is not ready to depart, take off slot lost
Location steering through signals	Incentives for airlines to operate from less busy terminals
Getting more out of existing assets	Faster turnaround through shorter time between take-offs/landings
CAPEX project acceleration	Fast track passengers with short connection at security
Independent connection delivery	Private operators adding check-in desks beyond airport authority
Anticipatory investments	Extra security lines to be added before the holidays
Flexible asset deployment	Early-morning or late-night flights to ease pressure on peak slots

Source: BCG analysis

Resolving Bottleneck #2: Connection Delivery | Multiple examples of grid operators implementing them

Commercial levers

Tiered connections

Interruptible connection contracts for large loads as flexibility option; under this tiered offer, a transmission-connected customer can opt for reduced tariffs in exchange for being interruptible
– implemented in 2023

Time-dependent transmission contracts guaranteeing grid access ~85% of the time while allowing curtailment during peak periods notified at least one day in advance
– announced in 2025

"Connect & Manage" (ERCOT), with fast grid connection for new generators with congestion managed through new lines planning and upgrades but with (temporary) curtailment risk for generators connected via this scheme
– implemented in 2021

Scrutiny on contracted capacity

ACM policy requires grid users to prove that reserved capacity will be used within 2 years or risk losing it
– rule adopted in 2023

Location steering through signals

Regional connection fee structure to steer projects to grid-favorable areas; it adds a power-based tariff by region on top of standard connection fees, imposing extra charges for new generation in already generation-heavy zones
– decision expected in 2025 (pending regulatory approval)

Even if dating from before the queue issues, in the UK this lever has been applied with regionally differentiated grid tariffs to generators, creating locational price signals to steer project development, shaping where new generation connects
– implemented in 2005

Infrastructure levers

Getting more out of existing assets

Real-time monitoring and AI to dynamically uprate line capacity. This boosts transmission in ~90% of hours vs. static limits, increasing throughput on existing lines
– implemented in 2020

In New York, utilities installed DLR systems on select congested transmission lines. Results have been striking – for 94–97% of operational hours, dynamic ratings exceeded the old static ratings, yielding on average a 47% increase in usable line capacity
– implemented in 2015

CAPEX project acceleration

Long-term supplier partnerships with multi-year frame contracts to cable and converter manufacturers for 2GW offshore grid programs to secure long-term supply capacity, accelerate delivery and hedge price increase
– implemented in 2022-2023

Germany amended its Grid Expansion Acceleration Act (NABEG) to designate key transmission projects as “overriding public interest”, enabling faster permitting by streamlining environmental reviews, limiting legal appeals, and prioritizing administrative capacity
– implemented in 2019

Independent connection delivery

Open connection delivery on the transmission level to independent players, based on the iDNOs (Independent Distribution Network Operators) model, increasing competition in grid delivery and accelerating connection of renewables and new loads
– approval pending

Governed by the AEMC’s TCAPA Rule, certain transmission connection assets can be designed, constructed, and owned by third parties rather than only by grid operators, as long as they follow the functional specifications from the TNSP
– implemented in 2017

Anticipatory investments

Overbuilt grid node for future offshore wind, with federal support to construct a major switching station in Connecticut sized for 2.4 GW of offshore wind injection vs. current projects that are only a fraction of that capacity, and rest is reserved for anticipated lease areas
– announced in Aug 2024

Right-sized distribution grid replacements to get ahead of EV and solar growth. When aging overhead lines in suburbs are due for renewal, Western Power is now installing higher-capacity cables than what the current load requires
– implemented in 2023

Flexible asset deployment

Tema’s pilot storage portfolio totals ~50 MW, entirely owned and operated by the TSO, located at strategic HV nodes in Sicily and Sardinia to cut congestion and provide ancillary services – first units commissioned in 2014 (35MW) and expanded in 2018-21 (15MW)

New Large-Energy-User connection policy will oblige data center applicants to install on-site batteries (or equivalent dispatchable resource) equal to their peak demand, enabling load-shedding or export during system stress
– expected implementation in 2025

Note: ACM = Authority for Consumers and Markets (Netherlands), DLR = Dynamic Line Rating, iDNOs = Independent Distribution Network Operators, DNO = Distribution Network Operator, AEMC = Australian Energy Market Commission, TCAPA = Transmission Connection and Planning Arrangements, TNSP = Transmission Network Service Provider, HV = High Voltage; Source: BCG analysis

Zoom—Tiered connections | Multiple countries are advancing on the concept of flexible connections, with different design choices made

Design option space for flexible connections offering

Domain	Options		
Type	Firm ramped connection	Interruptible connection	Time-restricted connection
Curtailment notice	Real-time	Day-ahead	
Duration	Temporary solution until firm connection	Permanent solution with compensation	
Curtailment Activation Method	Pro-rata *(Curtailment shared based on capacity)* (for permanent)	LIFO *(Last-in projects curtailed first)* (for temporary)	Priority-based *(Non-critical loads first)*

Examples of grid operators offering flexible connections

Time-dependent transmission contracts, unlocking up to 9 GW of new projects by guaranteeing grid access ~85% of the time (curtailment up to 15% of the time), with curtailment notified at least one day in advance; discount up to 65% of grid fees

Two types of limited-access connections for large users: (1) customers accept an indefinite non-firm connection in exchange for ~53% lower grid fees and a faster connection; (2) for temporarily limited connections (until a firm one is possible), the tariff is a weighted average of the standard and limited tariff

"Flexible connections" that let generators connect up to a decade sooner by agreeing to real-time output limits during network constraints, typically only a few percent of hours in the year, managed through a LIFO curtailment priority

SPP's Conditional High-Impact Large Load (CHILL) service allows large loads (≥ 10 MW at ≤ 69 kV or ≥ 50 MW at > 69 kV) to interconnect in ~90 days, with the condition that they accept curtailment during system stress or emergencies; curtailment is priority-based, with non-critical loads interrupted first, as part of the service agreement

Under a non-firm connection agreement, users may connect ahead of reinforcements but accept curtailment before firm-access customers. In constrained areas, reductions for multiple non-firm users are shared pro-rata across their contracted flexible demand. This is a connection condition, not a remunerated service, until firm access is granted.

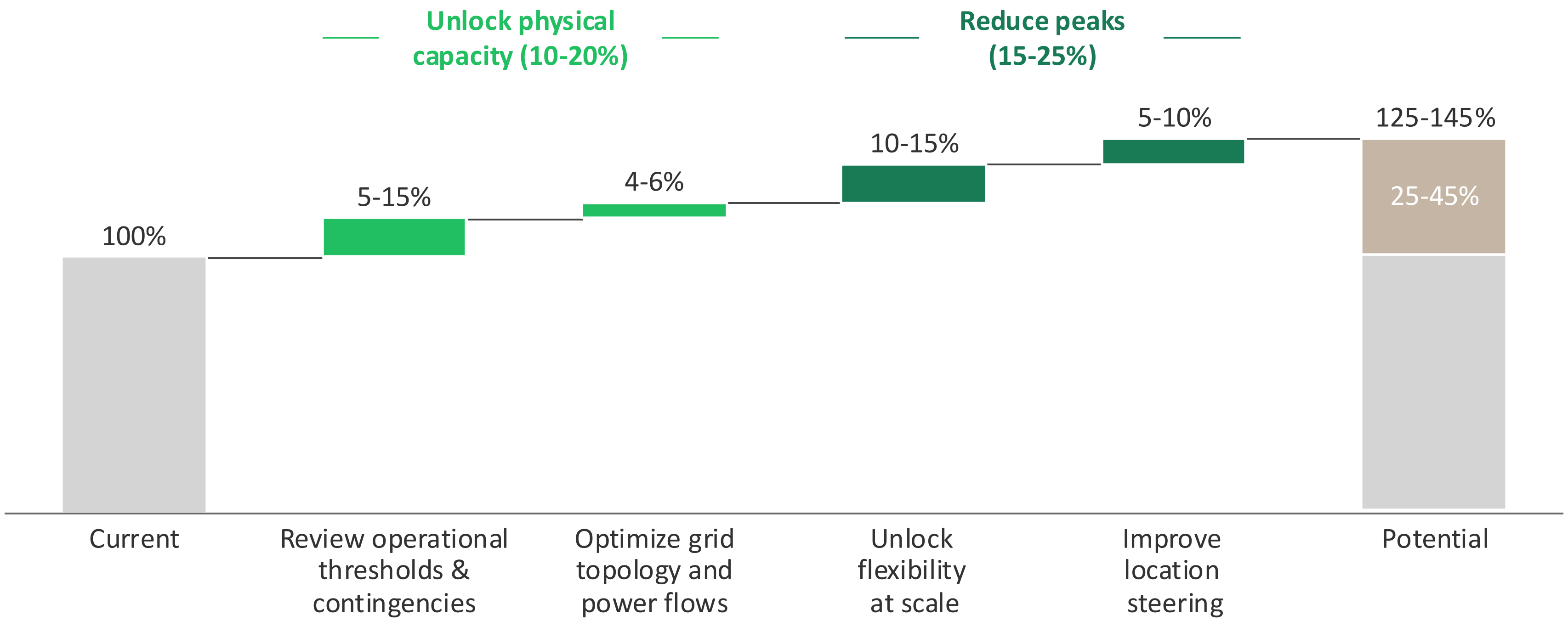
Potential roadblocks to solve

- **Execution risk increases for the grid operator** if a temporary connection contract sets a firm date for switching to a permanent connection; any delay in the CAPEX program may trigger penalties or compensation obligations, and so de-facto the grid operator takes a CAPEX delivery commitment
- **System and process complexity demand redesign**, as current dispatch, forecasting, and compliance tools have traditionally not been set up to manage dynamic connection statuses, notice windows, or curtailment enforcement

Source: BCG analysis

Zoom—Getting more out of existing assets | We could get more out of our existing grids

Grid capacity breakdown and estimated improvement potential (in %)

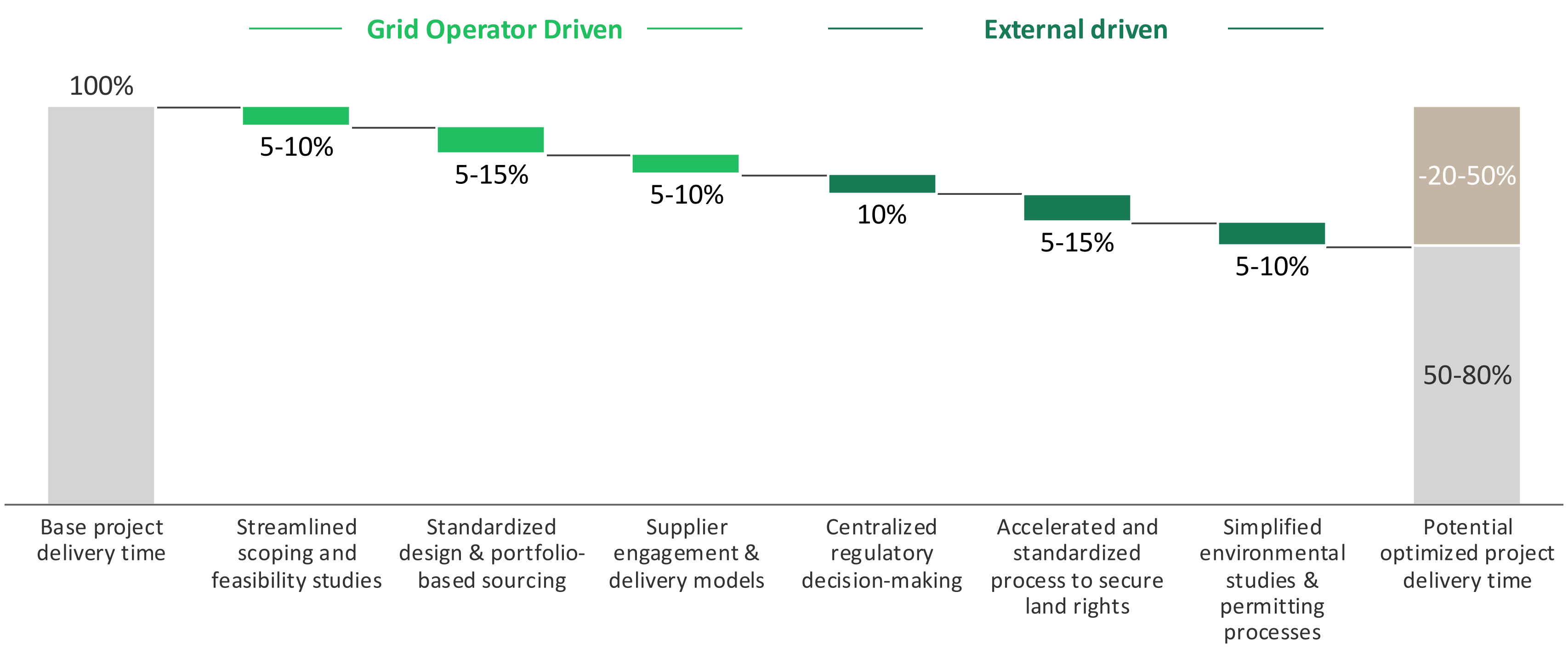


- Up to 25-45% grid capacity can be unlocked without new cabling
- Physical headroom comes from dynamic line rating, thermal efficiency, redesigning flows, and smarter grid planning
- Peak load can be flattened via behind-the-meter flexibility, enabled by the right incentives (such as dynamic tariffs)
- Requires risk-informed, digital and dynamic grids, with AI-driven analytics and scenario-based design

Source: Netbeheer Nederland (IBO); Federal Energy Regulatory Commission; National Grid; ABB; NREL; ERCOT; Brattle Group; Nicholas Institute at Duke; BCG analysis

Zoom—CAPEX project acceleration | Delivery times can be reduced significantly

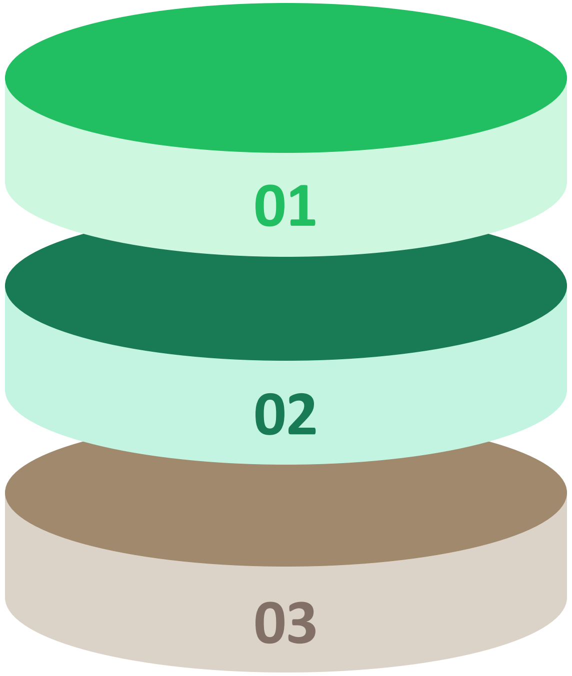
Acceleration potential for typical transmission projects (in %)



Note: Impacts are not strictly additive, as several activities may occur in parallel;
Source: TenneT "Acceleration package for grid capacity expansion" (2025); BCG project experience across markets globally

- Coordinated action across 6 levers can reduce delivery time by up to 20-50%
- Major gains from faster site selection, permitting, and supply chain alignment
- Applicable across substations, overhead line upgrades, and expansions. Smaller potential for asset replacement projects

Three dimensions are important in assessing which of these levers to implement



IMPLEMENTATION COMPLEXITY

Focus on levers that can realistically be executed

- **Complexity:** Can this lever be executed with existing capabilities or does it require lots of innovation?
- **Magnitude of change:** How disruptive is this change operationally or organizationally?

REGULATORY COMPLEXITY

Focus on levers that are acceptable for regulators/policymakers

- **Magnitude of change:** How disruptive is this change on the regulatory side?
- **Acceptability:** Is this likely to gain regulator/policymaker support on the short term (e.g., favorable for customers, nondiscriminatory, aligned with competition law and legislative frameworks)?

VALUE FOR SOCIETY

Focus on levers that have a positive impact on society

- **Grid capacity optimization:** Does this increase available capacity / number of realized customer connections?
- **Alignment to policy goals:** Does this contribute to policy priorities? This requires policymakers to clearly define which priorities matter most

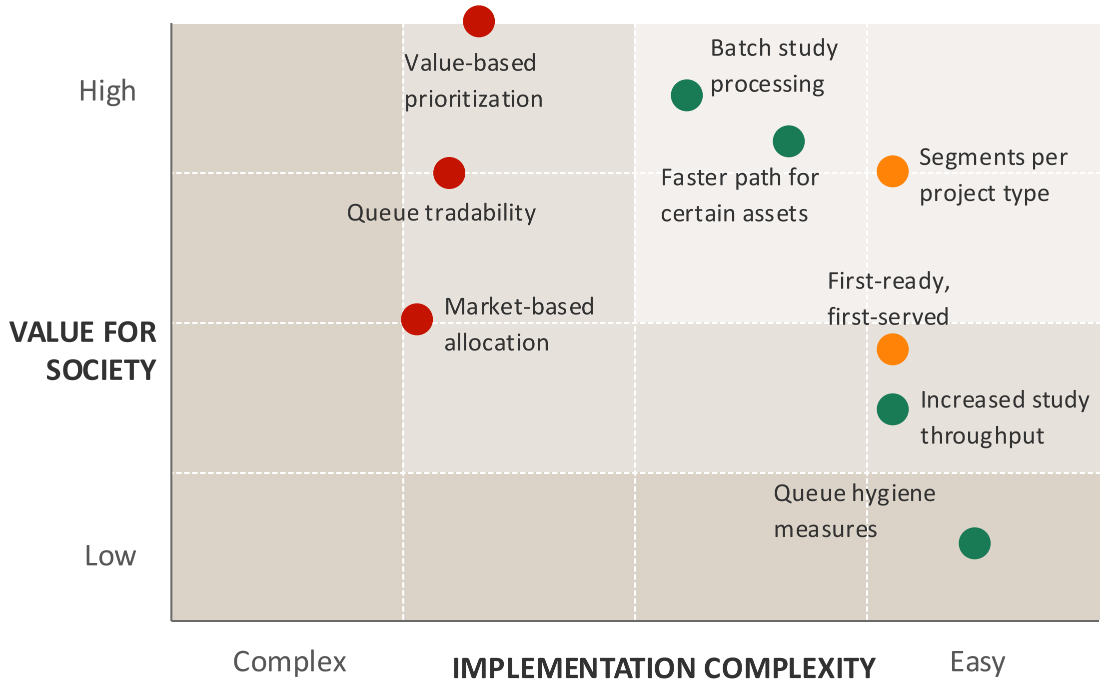
How do the identified levers score on these 3 dimensions?

Source: BCG analysis

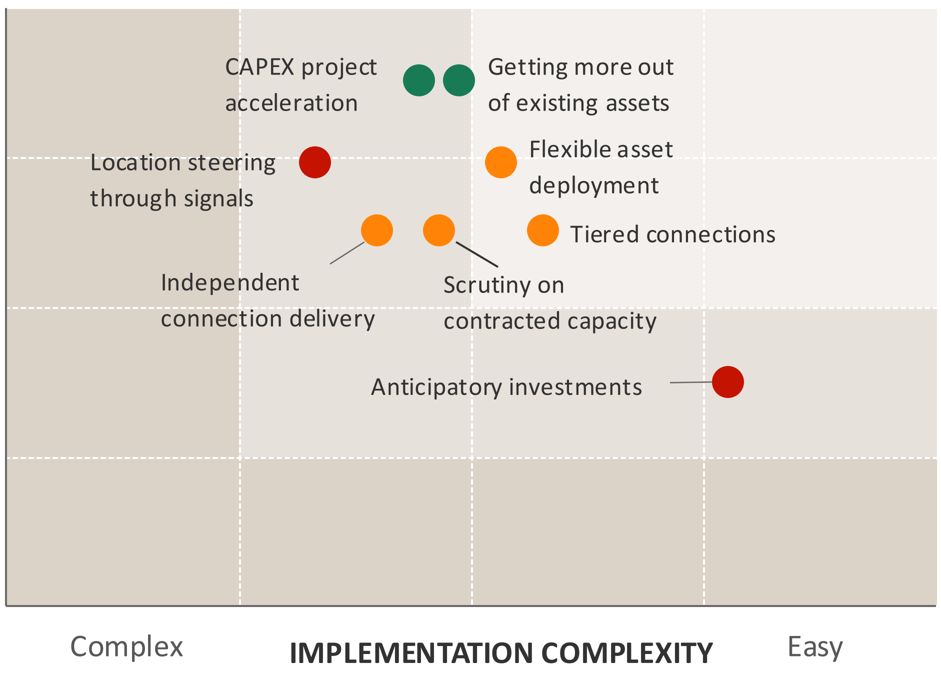
Scoring depends on local market and regulatory context

Illustration for a typical NW-European market

1 Levers to mitigate connection study bottlenecks



2 Levers to mitigate connection delivery bottlenecks



Legend: REGULATORY COMPLEXITY

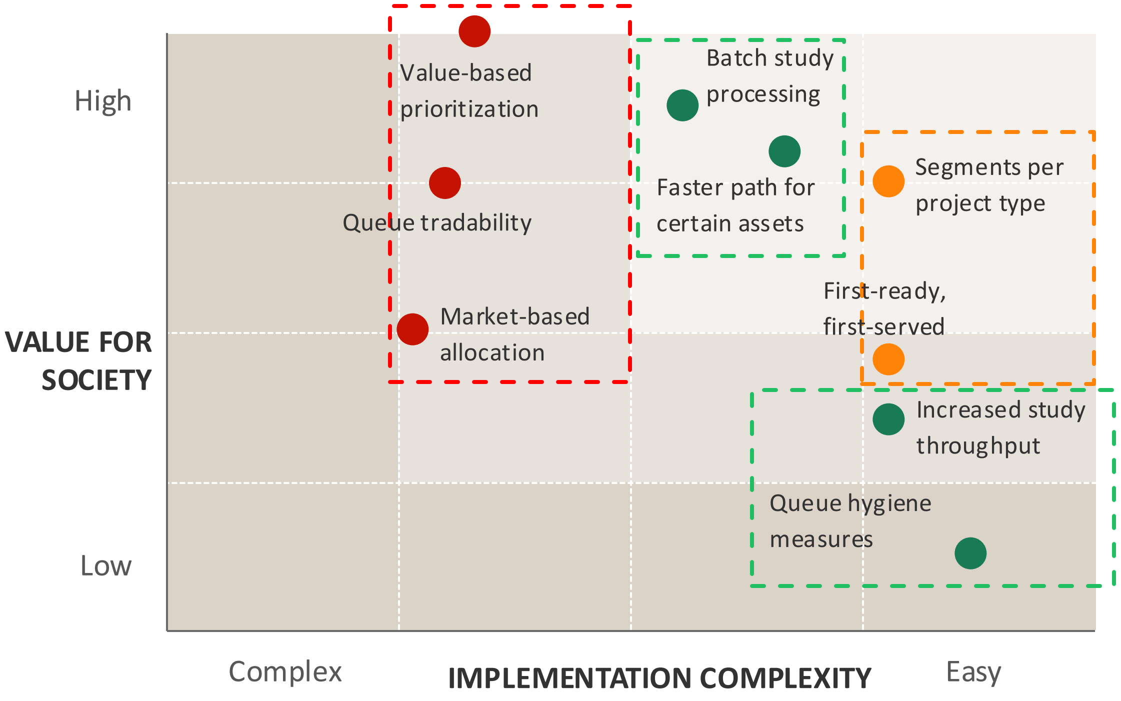
- Low regulatory complexity
- Medium regulatory complexity
- High regulatory complexity

Source: BCG analysis

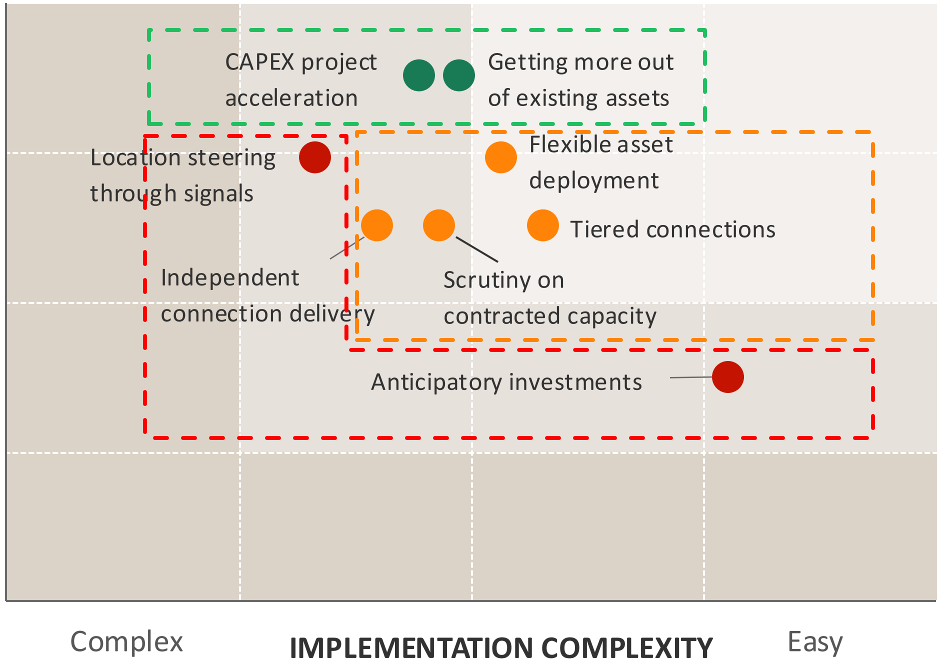
This allows to categorize levers into three groups of how to implement them

Illustration for a typical NW-European market

1 Levers to mitigate connection study bottlenecks



2 Levers to mitigate connection delivery bottlenecks



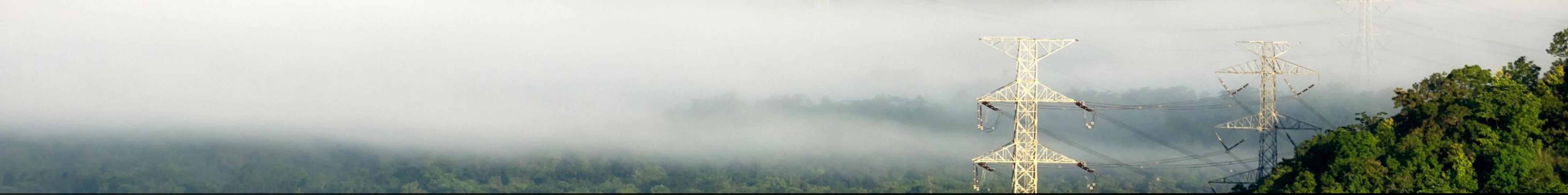
Legend: REGULATORY COMPLEXITY

- Low regulatory complexity
- Medium regulatory complexity
- High regulatory complexity

Legend: NEXT STEPS

- No-regret action
- To be investigated for near-term impact
- To be investigated for longer-term impact

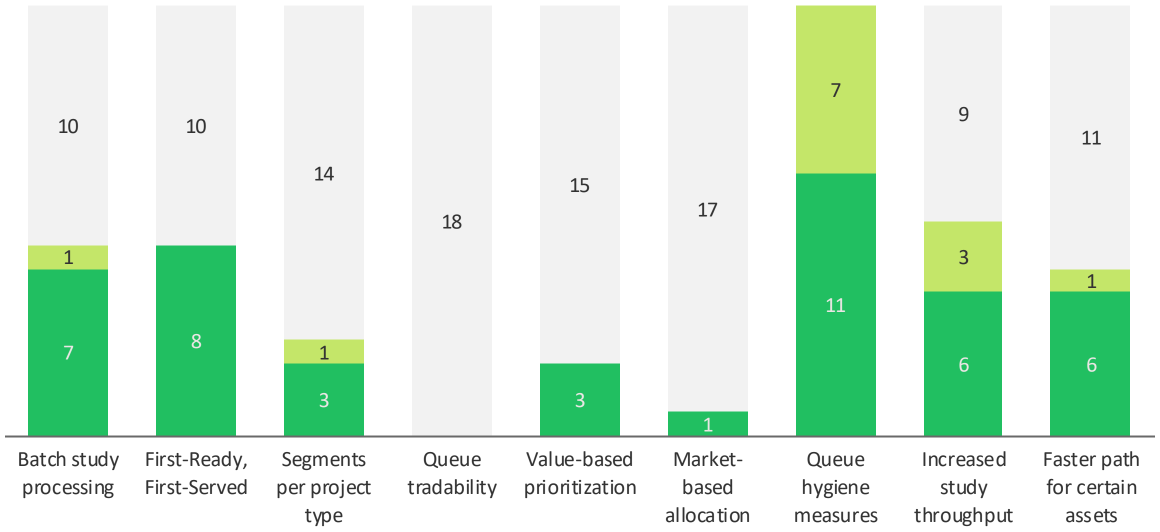
Source: BCG analysis



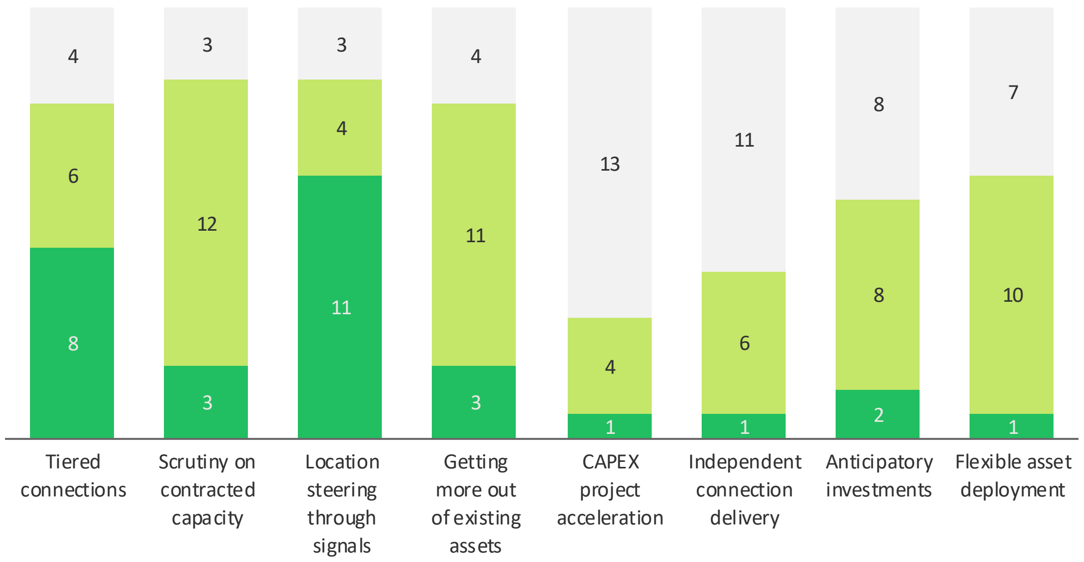
Lever implementation varies across markets—so far only the UK engaged in holistic connection reform, impact still to be proven

Number of markets that have implemented the different levers (18 markets analyzed: 6 in the US, 1 in Australia, and 11 in Europe)

1 Levers to mitigate connection study bottlenecks



2 Levers to mitigate connection delivery bottlenecks



Implemented | Being implemented or partly implemented | Not (being) implemented today

Note: US: PJM, ERCOT, CAISO, SPP, MISO, NYISO. Europe: UK, Germany, France, the Netherlands, Belgium, Denmark, Spain, Italy, Finland, Norway, Ireland. AU: NEM.
Source: BCG analysis

Market designers must clarify their guiding philosophy for reforms and focus on levers consistent with that philosophy

"The Five Forces Transforming Power Markets" (2024 BCG publication)

Different connection reform levers better suit different reform philosophies, whereas some can be applied independent of the chosen reform philosophy

We introduced a framework of three philosophies for how designers can reform power markets	Levers to resolve connection studies bottlenecks	Levers to resolve connection delivery bottlenecks
1 **Augment the market** Core belief: A market-based approach is the right way forward—however, we need to augment it with the right features to navigate today's challenges	• First-ready, first-served • Queue tradability	• Tiered connections • Location steering through signals • Independent connection delivery
2 **Complement the market** Core belief: The market alone is insufficient—we need to complement it with other mechanisms to get to desired outcomes for society as a whole	• Segments per project type • Value-based prioritization • Market-based allocation	• Scrutiny on current capacity • Anticipatory investments
3 **Forget the market** Core belief: Market signals are insufficient to deal with today's challenges—we need to increasingly look at regulation and central planning	*Centralized spatial planning with capacity targets and mandatory zones for load, storage and generation connections* *Central vision for sectoral decarbonization roadmaps to sequence electrification*	

Levers applicable across the three philosophies

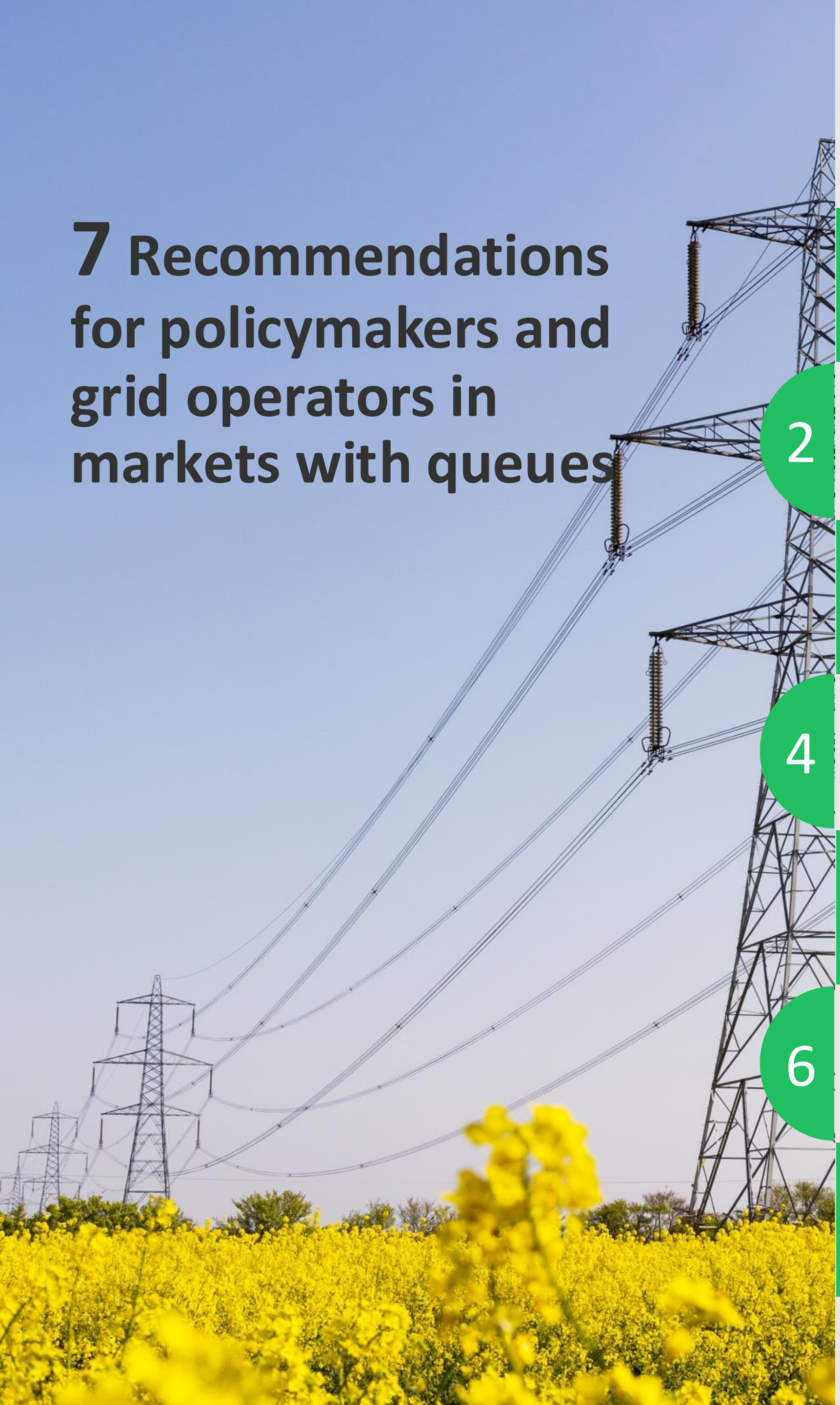
- Batch study processing
- Queue hygiene measures
- Increased study throughput
- Getting more out of existing assets
- CAPEX project acceleration
- Flexible asset deployment

While this document focuses especially on ways to augment or complement the market, policymakers must ask:

"Can even an augmented or complemented market resolve these bottlenecks adequately? Or is some level of spatial planning and central coordination needed to transform how we manage and deliver connections?"

Source: BCG analysis

7 Recommendations for policymakers and grid operators in markets with queues



1. **Re-imagine how grid connection studies are performed today:** Streamline the study process, by standardizing methods, adapting granularity to the right level through the connection funneling process, using automation and AI, and grouping connection requests in time-based batches to be able to process more and optimize grid studies

2. **Get more out of existing assets and accelerate delivery:** Understand true asset limits and unlock headroom through advanced analytics, modernized risk frameworks, and dynamic operating practices. For new assets, leverage standardized designs, strategically engage with suppliers, improve project controls, and treat permitting as a mission-critical item

3. **Clarify your reform philosophy, and make connection reform consistent with your market design approach:** Work with regulators to clarify your guiding philosophy for reforms (augment the market, complement it, or shift toward more central planning), and ensure consistency across reforms in grid connection and market design

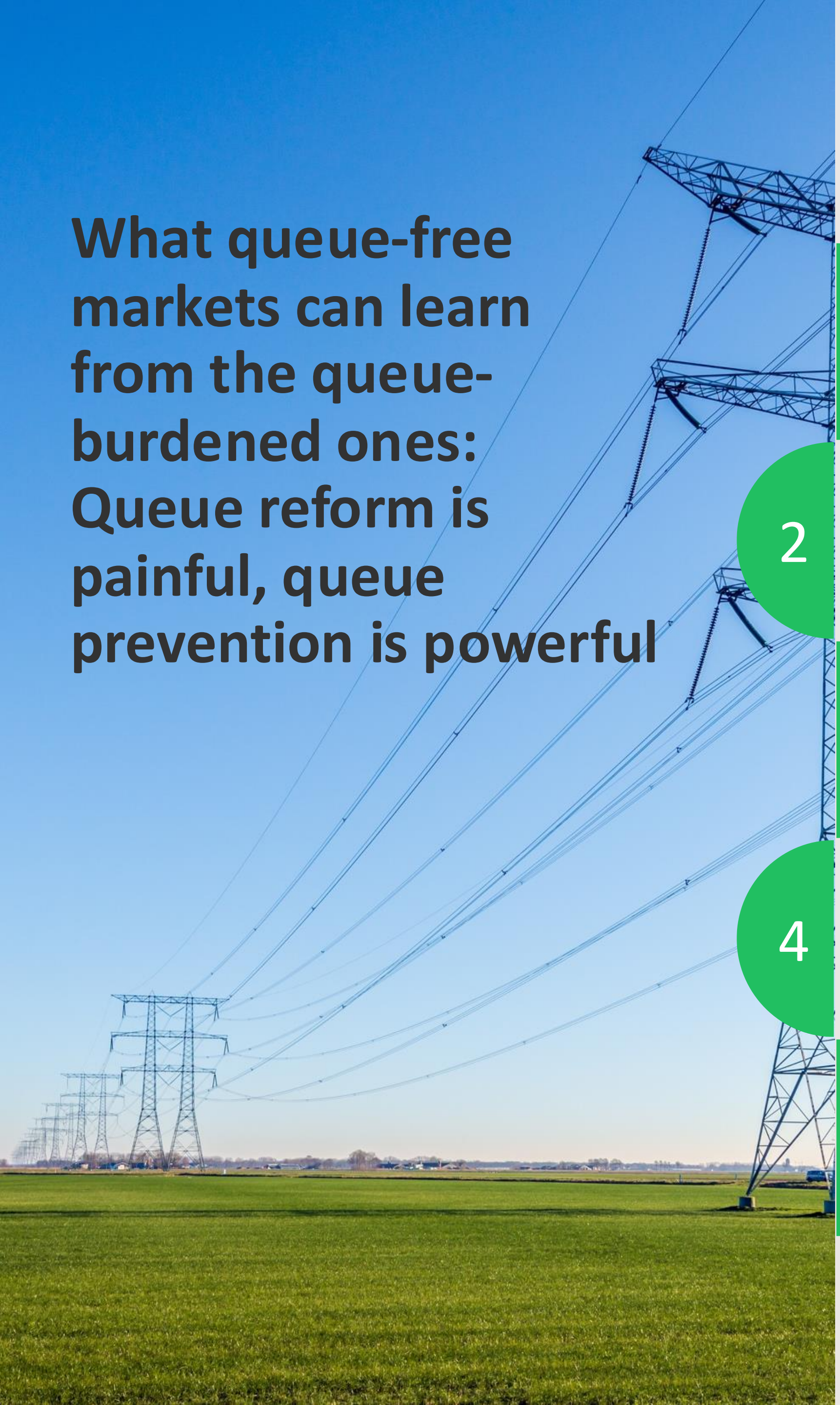
4. **Prepare implementation of no-regret and near-term impact levers:** Apply stricter queue hygiene to minimize risk of speculative applications clogging the system, and, together with the regulator, design high-value levers that require regulatory changes, including for example study slots by project type, flexible connections, and "use-it-or-lose it" logics

5. **Assess value and practical feasibility of identified longer-term levers:** Conduct a structured evaluation of the medium-to-long-term levers. Prioritize those that offer high societal value, but consider pilots to derisk uncertain concepts for at-scale delivery

6. **Learn from other sectors that have tackled similar challenges at scale:** Grid connection queues may be relatively new, but the underlying dynamics are not. Lessons from sectors like aviation, public transport, telecom, gas, and the entertainment industry, where capacity constraints and access prioritization are routine, can offer valuable playbooks

7. **Design reforms to evolve over time:** Queues are dynamic: project volumes fluctuate, behaviors shift, and policy priorities evolve. Reform frameworks must be adaptable, capable of being updated as conditions change, rather than assuming today's solution will hold indefinitely. Build in review cycles to ensure continued relevance and effectiveness

Source: BCG analysis



What queue-free markets can learn from the queue-burdened ones: Queue reform is painful, queue prevention is powerful

1. **Put market design philosophy at the heart of how you manage connections to the grid:** Your philosophy on access, whether to augment, complement, or centrally plan, should be coherent across grid and market reforms. Don't treat connection processes as a side track. Align them with the direction of your electricity market redesign from the start

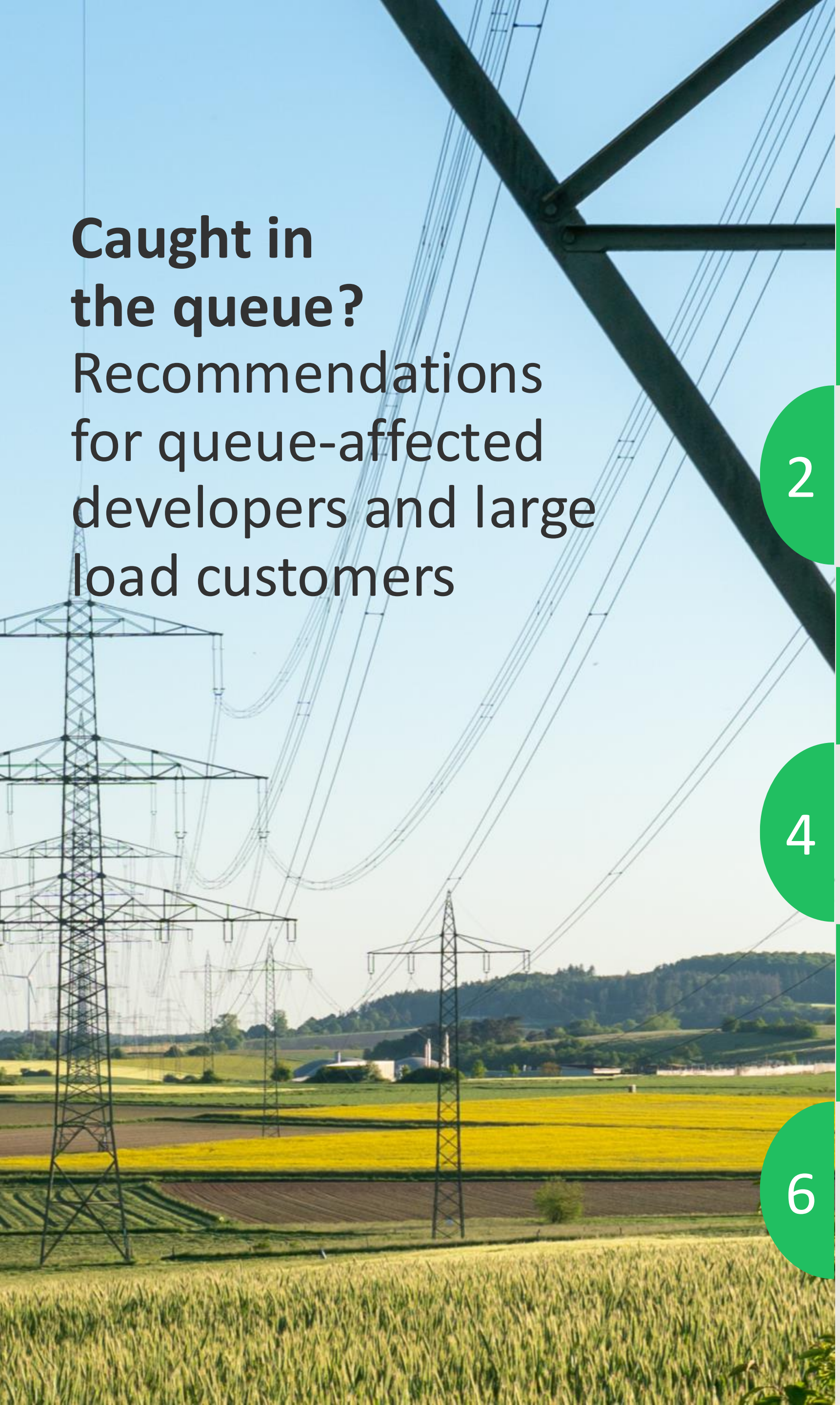
2. **Define what customers should expect from the grid, and align connection rules accordingly:** With your market design philosophy in mind, clarify what level of access, reliability, service, and responsiveness the grid is expected to offer to different types of users. These expectations will shape how much flexibility you retain in choosing your queue management strategy

3. **Harden your queue from day 1:** Apply strict queue hygiene even when the queue is short. Set expectations early: require deposits, permitting milestones, and readiness checks to prevent speculative applications from accumulating. Delayed action on this has been the root cause of queue bloat in other markets

4. **Institutionalize connection visibility and signaling:** Publish heat maps, future capacity outlooks, and provide zonal signals to guide developer siting and investment, before queues form. Create transparency on where capacity will be, not just where it is today

5. **Build for throughput, not just equity:** First-come, first-served may sound fair, but it doesn't scale. Adopt prioritization based on readiness and system value before volumes explode. Countries that tried to retrofit to "first-ready" or "value-based" prioritization face resistance from those that are impacted

Source: BCG analysis



Caught in the queue? Recommendations for queue-affected developers and large load customers

1. **Sharpen your readiness profile:** With reforms, projects that show maturity are far more likely to retain position or accelerate. This includes securing and demonstrating key permits early, aligning financing with connection application phases, and engaging with TSOs/ISOs on transparency around milestones to stay "queue-credible". But be strategic: increased readiness comes at a cost, so consider the trade-offs based on project risk, timing, and competitiveness

2. **Prepare for flexible connection offers:** Several regions are introducing flexible or non-firm access as default. Projects that are ready to operate under curtailment or staggered commissioning may get connected sooner. This includes exploring business model viability under partial or interruptible access, and optimizing asset design for modular or flexible operations. And be ready to flag that flexibility in discussions with the system operator

3. **Rethink behind-the-meter and co-location strategies:** Unlimited connections can no longer be taken for granted. Evaluate how pairing with load or on-site generation can improve the favorability and feasibility of your grid request. Consider co-location, storage integration, or behind-the-meter assets as ways to strengthen your connection case

4. **Know the value of your grid connection or queue position**: Whether you're waiting for a new connection or sitting on existing capacity, understand what your connection or spot is worth. Even in markets where queue trading is not formalized, explore informal ways to engage on the value of your connection or spot. Consider exits, partnerships, or capacity sharing, but approach them with care and transparency

5. **Understand the politics of coalitions and reform:** Forming coalitions can amplify your voice in shaping reforms, but be mindful of diverging interests. Not every player shares your urgency, technology type, or risk tolerance. Focus your collaboration efforts where alignment is strong, and avoid over-investing in consensus that will not materialize

6. **Track reform in your region, and beyond:** Our benchmark shows wide divergence in reform speed and approach. Learning from other markets can inform lobbying efforts, but equally important for international developers is to use this intelligence to prioritize regions where queues are short or reforms will be in your favour

Source: BCG analysis

Thank You.

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