BCG | CENTER FOR Energy Impact

Powering AI through grid-positive data centers

How flexible data center connections and operations accelerate energization and lower total system costs — a Northwest Europe perspective

Objectives of this publication

1 Show why data centers need a faster, more grid-positive path to power, and why, done well, they strengthen rather than strain the grid

2 Quantify what flexible connections and behind-the-meter assets deliver, for the data center and for the system as a whole

3 Set out practical actions for key stakeholders, and the open questions that will determine how far grid-positive data centers can scale

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Preface

The contest for leadership in AI is also a contest to build and power the data centers behind it, with the economies that host that compute capturing significant value and a measure of technological sovereignty. Global compute capacity is expected to more than double by 2030, and securing a share means connecting data centers at an unprecedented scale and speed – with connection queues in many markets now running five to ten years. Power has become a decisive constraint on where data centers are built and how fast – alongside access to fiber, gas, cooling, and water.

Much of this investment is also mobile. A growing share of AI workloads are not latency-sensitive, so the compute can locate wherever power is most competitive or can be secured first. Connection speed has therefore become a lever in the competition between markets and regions.

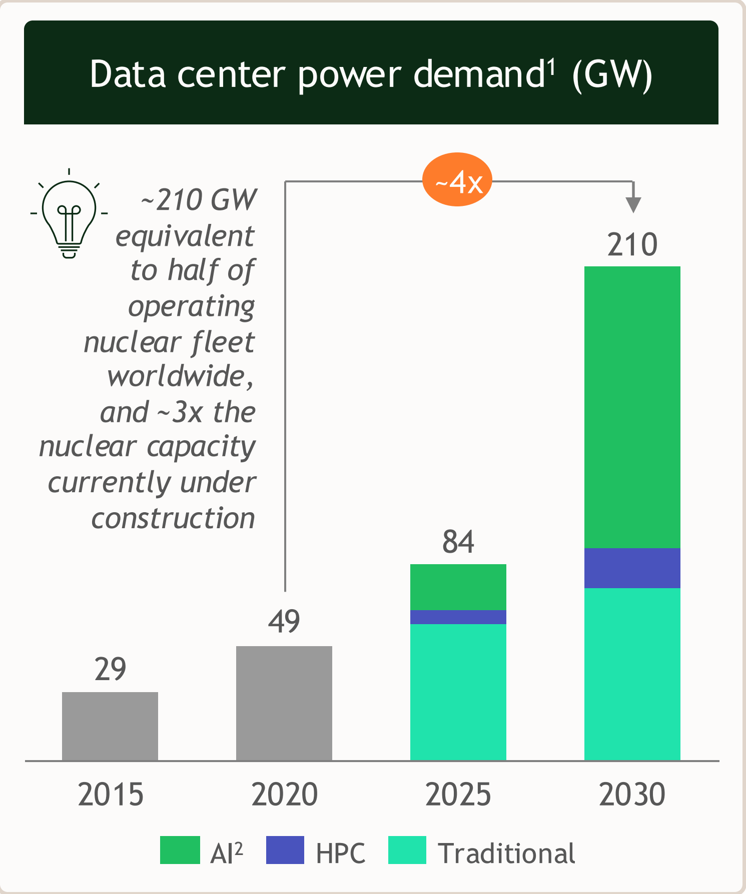
Locally, though, data centers often face opposition. They are challenged for raising costs for other users, lengthening connection queues, inflating grid investment, and competing for scarce low-carbon power. The concern is legitimate, but the outcome is not predetermined. Whether a data center burdens or strengthens the system depends on how and where it connects, and how it runs once it is online.

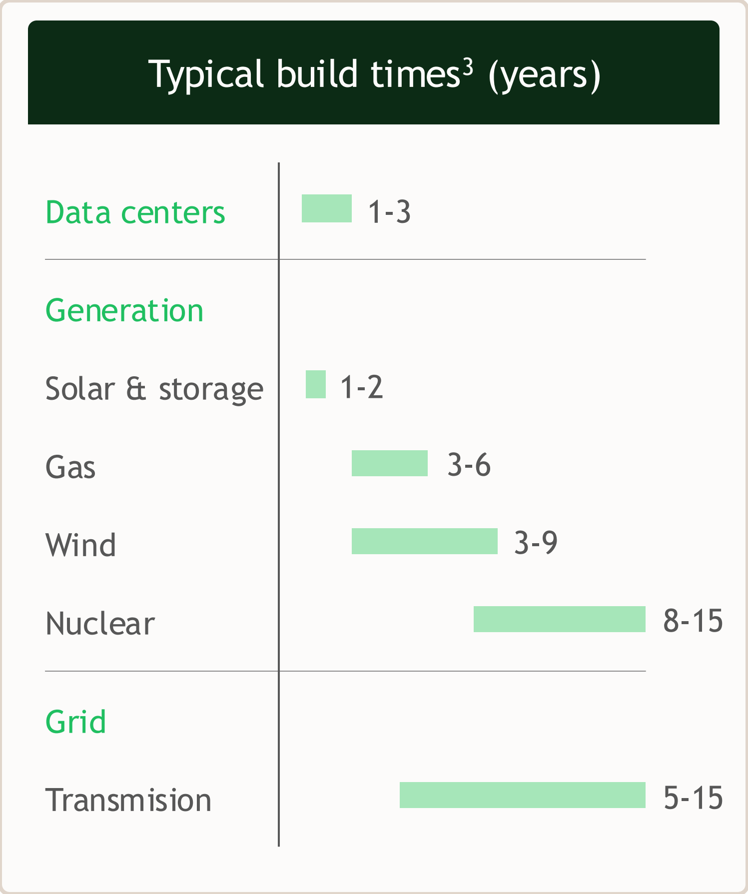
Although we firmly believe load growth is a key lever for electricity affordability - spreading fixed costs over more users, raising utilization, and letting demand materialize for which we are expanding our electricity systems - this publication does not take a position on how much data center capacity a given country should host: that is a societal and political choice. It instead starts from the premise that once a country has decided a certain amount of data center capacity is in its interest, there is a better and a worse way of hosting it. It argues that there exists a way for data centers to be online years sooner without pushing up costs for others. It rests on two key levers. First, connect in a different place than today and/or connect non-firm: accept curtailment in the hours the grid is stressed, in exchange for skipping the years-long wait for firm grid capacity. Second, build the capability to act on it: shift flexible workloads and draw on behind-the-meter (BTM) generation and storage. Done this way, grid-positive data centers can deliver measurable benefits to both the system and themselves.

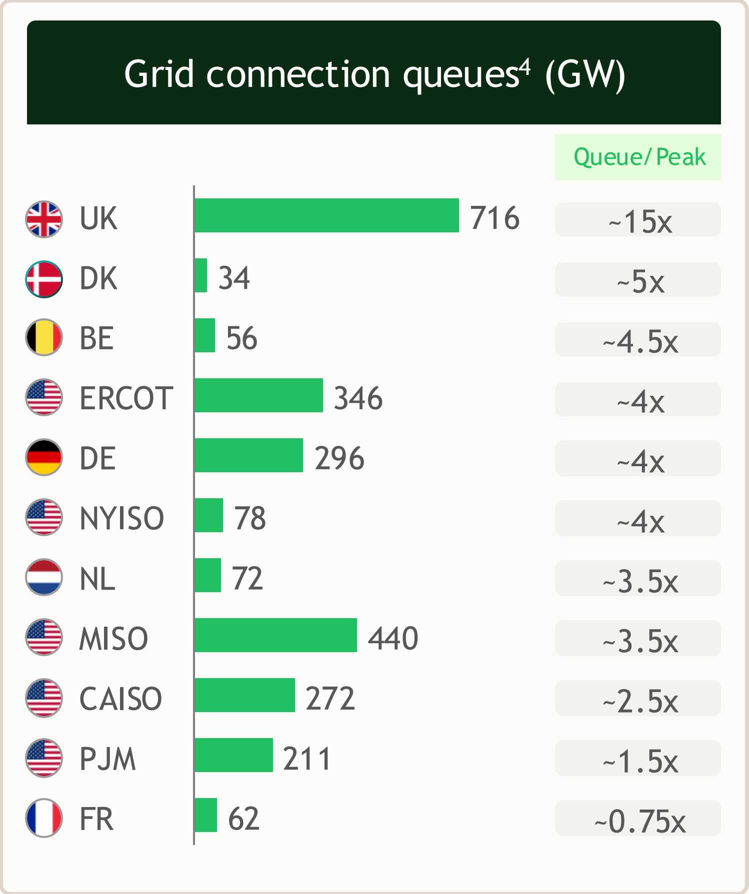
In Northwest Europe, the reality is that achieving this in already congested markets will require data centers to host significant BTM capacity. That adds to their power supply costs; in the cases we have studied, though, the value of energizing years sooner because of it outweighs this added cost. Even while that may be the case, under today's connection rules in many markets, data centers retain the right to wait for a firm connection wherever they choose to site, with non-firm access merely an option - so realizing this value in practice will likely require clear signals, commercial or regulatory, that connecting firm wherever a data center wants is simply not an alternative where it would negatively impact the system. None of this is a quick fix: it requires changing today's approach to siting, connecting, and operating data centers, and today's rules regarding BTM usage and permitting - and it will not be feasible everywhere. But where it is, grid-positive data centers should be the goal.

To quantify this, BCG has built a model that jointly optimizes load flexibility, BTM assets, and firm versus non-firm grid access to find the least-cost way to meet data-center demand. This publication focuses on Northwest Europe over a 2030-2035 horizon, and sets out what that means for each stakeholder.

Power is the decisive constraint for data center build-out, with large connection queues and waiting times across regions







Source(s): EIA; IEA; Lazard; US DOE; Expert interviews; 2026 BCG Global Data Center Model; BCG analysis.
1. Base case trajectory based on BCG Data Center Supply Model and AI Compute Demand Model, excluding China and crypto 2. AI compute demand spans GPUs, which provide general-purpose processing for AI training and inference, and ASICs, which are custom-designed to deliver higher efficiency for specific AI workloads, often used for AI inference 3. Assumes large-scale solar and storage; wind includes onshore (range lower end) and offshore (range upper end) 4. Transmission-level queue size compared to peak load, as per the latest publicly available data in Q3 2024.

In addition, data center build-out is often considered as a burden to the energy system

Longer queues	Higher bills	Rising emissions
Data centers take scarce grid capacity, lengthening connection queues and lead times for other users	*Data centers add demand faster than supply can be built — pushing up power prices for everyone else*	*Data centers take scarce low-carbon supply, pushing the system onto more carbon-intensive sources*
Data centers now represent up to 40–50% of the connection queue in some markets. In Belgium, their share roughly quadrupled (from ~4% to ~16%, 2022–25). Data centers even represented ~70% of the ERCOT connection queue in 2025	PJM capacity prices jumped ~10x in two years; its independent market monitor attributes 63% of the 2025-26 increase to data centers. In Europe, same concern is rising – policymakers insist data centers must connect without raising bills	Data centers already take approximately one-quarter of global corporate clean-power procurement (roughly one-fifth in Europe). In addition, where grids lag, developers increasingly consider building own gas-fired generators

These concerns are real - but a function of where and how data centers are connected and operated. Data centers can be "grid-positive" as well …

Source(s): PJM Independent Market Monitor; IEEFA; NRDC; Ember; S&P Global; Carbon Brief; Expert interviews; BCG analysis.

Grid-positive data centers can solve both of these problems — What is a “grid-positive” data center?

In this document, a data center is grid-positive when … it triggers little incremental grid or generation investment, while spreading fixed system costs over more consumption — or, at minimum, when the net effect of the two is positive for the system. This can be achieved through four levers:

	1	2	3	4
Energy efficiency	**Connection siting**	**Connection design**	**Operational flexibility**	**Behind-the-meter assets**
Reduces power consumption of the data center itself	Puts load where there is grid space and generation surplus	Connects non-firm to avoid large upgrades and increase speed	Moves load in time or space, or activates “virtual” flexibility	Optimizes grid interaction by relying on own BTM assets
Compute, cooling/power usage effectiveness (PUE), chip efficiency	*Brownfield industrial sites; co-siting w. power plants and connections*[1]	*Non-firm connections; taking less power during periods of congestion*	*Temporal or geo load shifting, or activating flex of neighboring loads*[2]	*Batteries, on-site firm generation (gas), on-site renewables (solar, wind)*
… but each lever comes with trade-offs	Typically farther from compute demand, adding latency	Periods of grid unavailability put compute at risk	Not every compute load can move, and not at every hour	These assets add to the cost base and require space/permits

Source(s): BCG analysis.
1. Some utilities offer this as “powered land” - sites where developers co-design data centers around existing power infrastructure to maximize utilization and accelerate speed-to-power 2. Data center operators are exploring how to activate this type of neighboring flexibility; beyond the technical coordination required, this also calls for new types of commercial arrangements between the parties involved.

Being grid-positive can help data centers to connect faster …

Potential benefits to the data center of being "grid-positive"

Shorter time-to-power and a **stronger license to operate** - reflected in the larger boxes below - are what make going grid-positive worthwhile for a data center. Lower energy and grid costs, on their own, are typically not enough of an incentive for data centers to site, connect, and operate this way.

Shorter time-to-power

Up to $8M per MW DC capacity installed[1]

Connecting sooner on non-firm terms brings forward years of compute revenue; worth several times its cost

> Main source of value

License to operate

Faster approvals and less local opposition

Faces less community and political resistance, and typically wins clearance to build faster – given its positive impact on the broader system

> Easier to site/permit

Lower energy cost

Lower annual energy cost[2]

Under a given grid connection, drawing from behind-the-meter assets and operational flexibility during peak hours can result in a lower power supply cost and profitability uplift

> Lower energy bill

Lower grid costs

Lower network tariffs

Lowers both the one-off connection charge and ongoing network tariffs, with the level varying sharply by country

> Lower upfront/ongoing costs

Source(s): BCG analysis.
Note: Connection charge and network tariff savings are highly market-dependent.
1. Cumulative present value of up to 3-year earlier energization over asset lifetime at 6% WACC 2. This reflects the energy cost benefit under a given grid connection. In practice, sizing BTM assets and operational flexibility to cope with a non-firm connection typically worsens the data center's yearly business case relative to a firm alternative; in the cases we studied, though, the upside of faster connection outweighs this added cost.

… and can deliver measurable system benefits

Order-of-magnitude NPV of broader system value per GW grid-positive data center in NW-Europe

Benefits apply to data centers where the design parameters on slide 6 can still be optimized

Higher grid utilization through load growth

$1-2bn

Cost recovery and returns for the grid gets spread over more demand, lowering per-unit network charges for existing users

Lowers network bills for all users

Value from load growth being grid-positive

$0.5-1bn

Less peak demand from a grid-positive data center reduces generation and grid build-out that a firmly connected & operated data center would trigger

Avoids new generation and grid build

Broader economic and strategic value of data centers

- **Power demand that catalyzes the energy transition**, accelerating low-carbon generation build-out
- **Additional system value** from monetizing idle BTM capacity during periods the data center doesn't need it
- **Strategic infrastructure and sovereignty**, shaping a country's position in an AI-enabled global economy
- **Economic benefits** related to the construction and operation of data centers, digital ecosystem development, and creation of a digital export industry

Source(s): ACER UIC Indicators (Jul 2023); UK DESNZ/GHD (Mar 2025); CREG B2464/B2891; Elia/TenneT/RTE/BNetzA tariff filings 2024; Elia; BCG "The Power of Compute"; BCG "Data Centres as Strategic Infrastructure: Unlocking Value for NZ Inc"; BCG analysis.

Note: "Higher grid utilization through load growth": NPV over 25 years. Tariff spreading benefit is the data center's own network payment under a capped allowed revenue, which equals the reduction in existing users' bills; order-of-magnitude estimations done for the transmission grid level. "Value from load growth being positive": sum of avoided peaker build and grid reinforcement vs. firmly connected and traditionally operated data centers, assuming ~50% of DC nameplate capacity avoided peak, generation capex of $1,000-2,000/kW, avoided grid 100-170 km OHL/UGC at 110-150 kV + transformer upgrades and civil works.

Yet this "win-win" is not possible in many congested areas today — making it real requires changes

Why it often doesn't work today

Situation today in congested areas
Without triggering major grid buildout, grid operators can typically only offer highly non-firm connections

That forces a BYOC-type setup
Firm, on-site BTM generation needed - operational flexibility, batteries and renewables alone rarely close the gap

But BTM rollout has its own limits
Siting/permitting limits (e.g., emissions or nitrogen rules) and long delivery times for firm generation

As a result, DCs often wait to connect firm — leaving value on the table for them & the system

Something has to give

Steer siting
Central guidance on where data centers should site — in areas with grid/generation headroom or buildout

And/or ...

Facilitate speedy BTM build
Policies that fast-track siting, permitting, and delivery of the firm BTM assets needed to operate on highly non-firm connections

Way forward

Strong case to develop a national data center strategy

Including how many to target given the benefits, where to site them, how to connect them, and what is expected in terms of BTM to not trigger negative system effects

Taking such a system-perspective approach parallels how for example Belgium identified the Doel and Tihange nuclear sites in the 1960s / 70s, and how other countries run their nuclear siting exercises today

Source(s): BCG analysis.
Note: BYOC = Bring your own capacity.

1. Locate differently: Puts new large loads where power is available, revives how heavy industry located a century ago

1 What grid-friendly siting means

Power already in surplus
Where excess generation exists and existing curtailment would benefit from additional load

New generation coming
Co-located with planned generation, so supply and load arrive together

Industry retreating
Brownfield sites of closing plants, inheriting connection and freed capacity

Aligned with grid build-out
Timed and placed to match planned network expansion, not force it early

2 The trade-off for data centers: location for latency

Training & batch inference EASIER
Latency-tolerant — run wherever power is cheap

Agentic & reasoning MODERATE
Some tolerance — regional siting works

Real-time, interactive inference HARDER
Latency-critical — must stay near users

3 Demand moves back to the power — as heavy industry did in the past

Before long-distance transmission became viable and reliable, the central logic of industrial siting was simple: **industry goes to energy.** Cheap, abundant, captive power shaped large load locations. While that logic disappeared with the widespread availability of grids, there is a flashback to that period as unlimited grid availability able to connect whatever or wherever is not anymore feasible or affordable

Aluminum smelters: the data centers of the industrial era

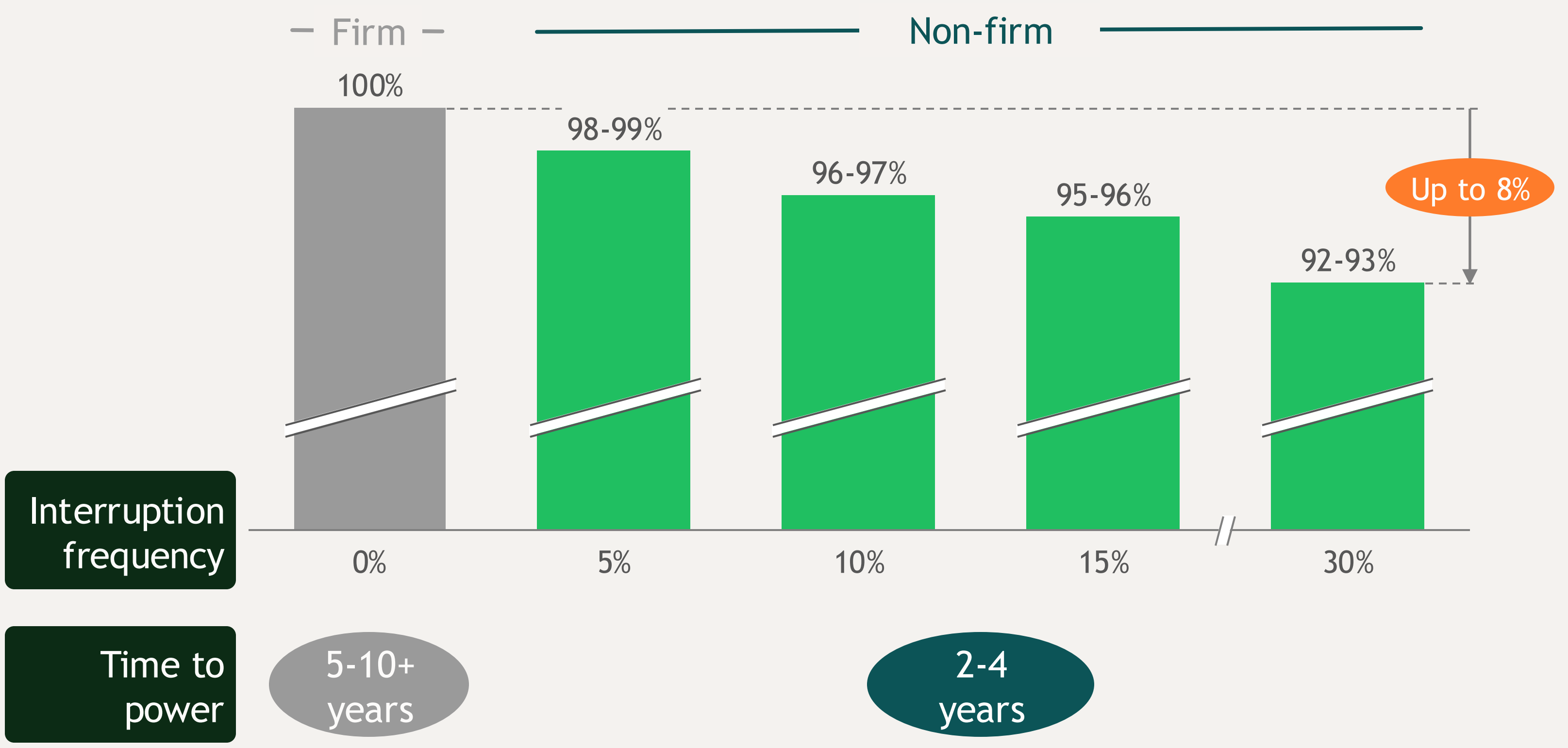
Vast, power-hungry loads that located wherever power was cheap and captive, often hydropower: e.g., at Niagara Falls (1895), at Shawinigan Falls (1901), and in Bell Bay (1955)

Smelters are clustered at cheap "baseload" power: global electricity mix ~57% coal, ~31% hydropower, ~10% natural gas

Source(s): EU Joint Research Centre; BCG analysis.

2. Connect non-firm: Makes data centers more grid-positive and allows to connect faster, but creates compute-at-risk

Annual share of compute demand served
Illustrative for a data center without behind-the-meter assets or load shifting



Flexible access can reduce time-to-power from 5-10+ years to 2-4 years by lowering the need for (major) grid reinforcement

Without mitigation, the compute gap can be material: for example, a 50% non-firm connection could leave even up to 8% of annual compute demand unmet if activated 30% of the year

Each 1% of unmet compute demand destroys ~1.5-2% of profit: fixed costs don't fall when revenue does, making even small reliability improvements highly valuable

Source(s): Expert interviews; BCG's DC BTM Optimizer; BCG analysis.
Note: Assumes 65-78% utilization rate of installed compute capacity and for non-firm connections 50% flexible and 50% firm.

3. Flexibilize load: Possible today but limited, expected to grow

Mechanism
How the load flexes

Type	Description	Availability today
Time	Move compute in time, e.g., defer training and batch inference to off-peak, lower-price hours	Emerging ●●○ Easily-deferrable share shrinks as real-time inference grows
Space	Route load across sites or regions with grid headroom. Requires multi-region orchestration within data residency barriers	Frontier ●○○ Real-time inference can't change regions
Virtual	Don't move compute, but source flexibility from a neighboring flexible (industrial) load that curtails on data center's behalf	Frontier ●○○ Works for any workload; largely unproven

Capability
Real today and expected to grow

Share of compute that is flexible is expected to increase

- **Google started to price by reliability tier:** guaranteed service at premium, interruptible "sheddable" compute at a discount with its Gemini "Flex" tier running ~50% below standard pricing
- Buyers increasingly consider **variable latency** and **best-effort delivery** for a lower price, letting providers run jobs **when compute is easier**
- These tiers track compute supply and demand; linking compute price to **grid conditions**, **power prices** or **carbon** is the emerging next step

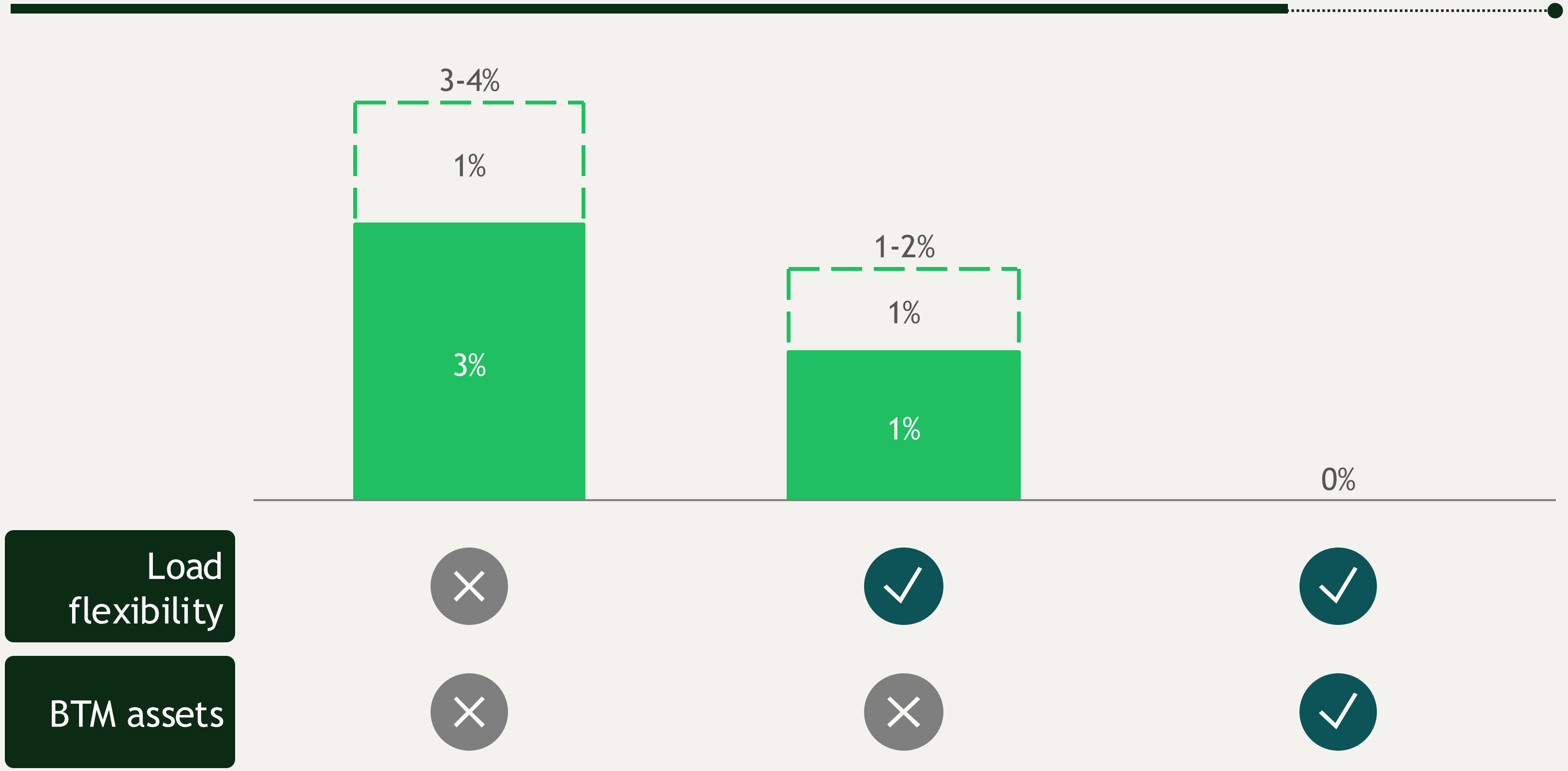
Workload	Can wait?	Pause?	Flexibility
Training/fine-turning	Yes	Yes	●●● High
Batch/async inference	Yes (<24h)	Yes	●●● High
Agentic/reasoning	Within minutes	Yes	●●○ Moderate
Real-time interactive	No	No	●○○ Low

Source(s): Reuters; Emerald AI; Nvidia; EPRI; SRP Phoenix demonstration at an Oracle facility (2025); Duke Energy; Expert interviews; BCG analysis.

4. Install BTM assets: Operational flexibility alone is typically insufficient to close the gap, behind-the-meter assets are needed

Annual share of compute demand not met

Illustrative for a data center with non-firm connection: 50% capacity reduction during 10% of the year



Under current technical capabilities, DC load flexibility can typically reduce unmet demand by only ~20-60%, but this might improve over time as DC operators further innovate[1]

Effectiveness varies by facility type: training workloads usually offer the most flexibility, while (certain types of) inference is less flexible because of real-time requirements

BTM assets such as batteries but especially gas turbines make it possible for DCs to accept non-firm connections while fully serving compute demand

Source(s): BCG's DC BTM Optimizer; BCG analysis.
Note: Excludes time-sensitive compute.
1. Even within inference workloads flexibility is likely to widen over time as service tiers and workload segmentation become more mature.

4. Install BTM assets: What data centers can put behind the meter

Firm generation

Gas turbines
Efficient, fast-starting, and can run for extended periods

Reciprocating/diesel engines
Fastest start, engine-based (diesel, gas), and modular

Fuel cells
Clean, quiet, easily siteable, but high cost and limited scale today

Variable generation

On-site solar PV
Cheapest clean energy, but intermittent and land-hungry

On-site wind
Low-cost intermittent clean energy where site's natural conditions allow; rarely viable on space-constrained DC campus

Storage

Batteries (e.g., lithium-ion)
Fast-responding, modular, and for short duration (hours); proven technology, sharply decreasing costs

Emerging storage technologies
Could allow for long(er) durations; but unproven at scale

Connective infra

Grid connection
Firm or flexible link to the power grid

Gas pipeline connection
Cost efficient fuel delivery

Fuel storage
On-site fuel buffer

As non-firm electricity connections typically lead data centers to rely on firm (gas-based) BTM generation, data center build-out can create meaningful new demand on the gas grid too — not just the electricity grid — with new connections and potentially additional infrastructure investment required

Source(s): BCG analysis.

4. Install BTM assets: Six factors determine the optimal BTM stack

How much BTM

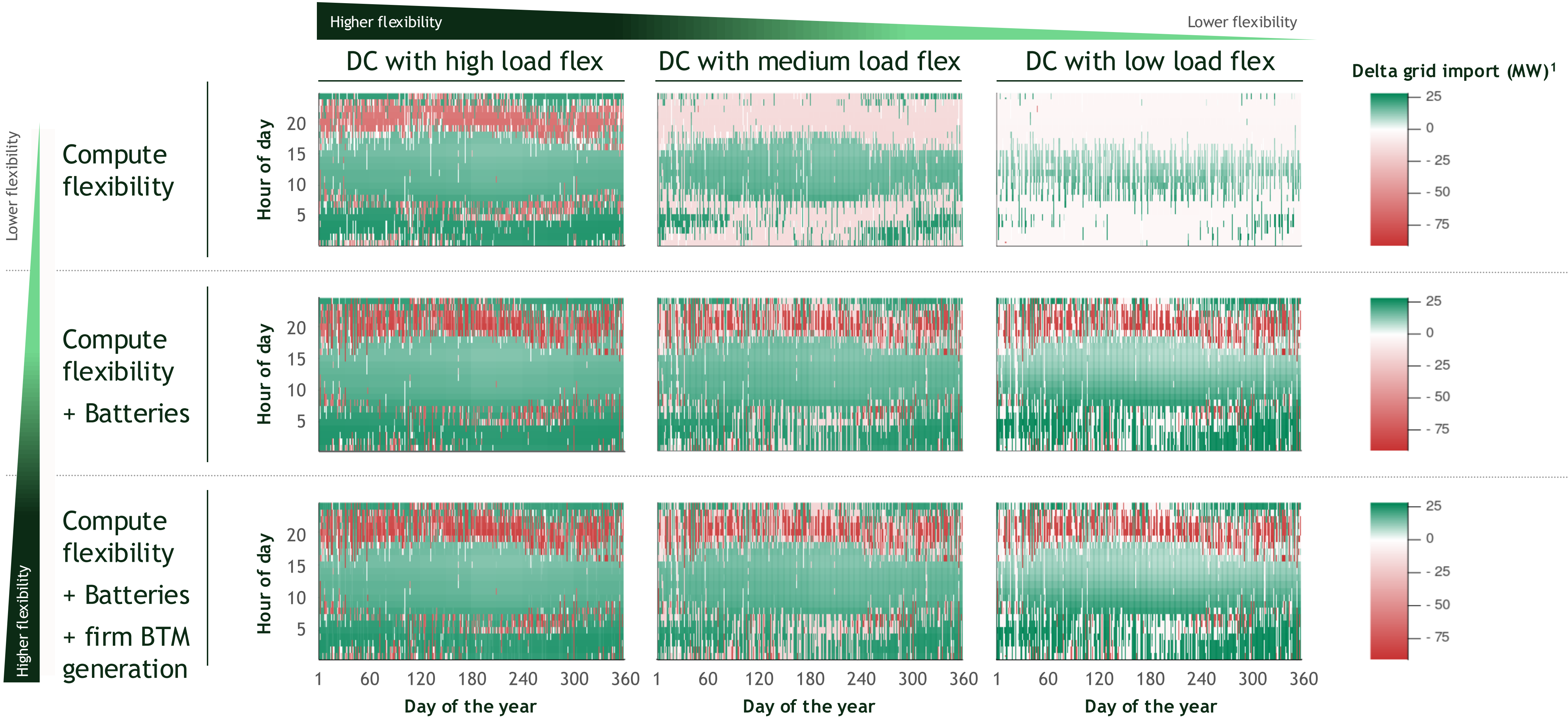
Firmness of grid connection	**Firmer connection:** Grid carries the load, minimal BTM needed	**Non-firm connection:** BTM required to guarantee uninterrupted operations
Inherent load flexibility	**Highly flexible load:** Less BTM required to cope with non-firm connection agreements	**Mostly inflexible time-sensitive load:** More BTM required to ensure time-sensitive load can be met

Which BTM mix

Physical site constraints	**Few constraints:** Enables on-site generation; easier to accept non-firm connection	**Dense or constrained setting:** Favors battery storage; difficult to accept non-firm connection
Asset delivery speed	**Fast delivery:** Optimal BTM mix is set purely by relative economics	**Long delivery timelines:** Slow-deploy assets are ruled out if they become the constraint
Gas fuel prices	**Low gas prices:** Onsite generation more economical	**High gas prices:** Batteries and onsite renewables win on levelized cost basis
Battery storage cost trajectory	**Little cost decrease:** More gas generation to carry BTM asset mix	**Strong cost decreases:** More batteries in BTM asset mix, overtaking generators

Source(s): Aurora Energy Research; EIA; Trading Economics; BCG's DC BTM Optimizer; BCG analysis.
Note: Carbon and sustainability commitments, while important to many operators, are treated as a second-order priority in this framework given the primacy of speed-to-power to many operators, with securing adequate BTM capacity to cope with non-firm grid connections or off-grid setups taking precedence —decarbonization of that BTM stack considered as a subsequent optimization.

Result: Operational flexibility & BTM assets allow data centers to reduce grid stress during congestion & system peaks

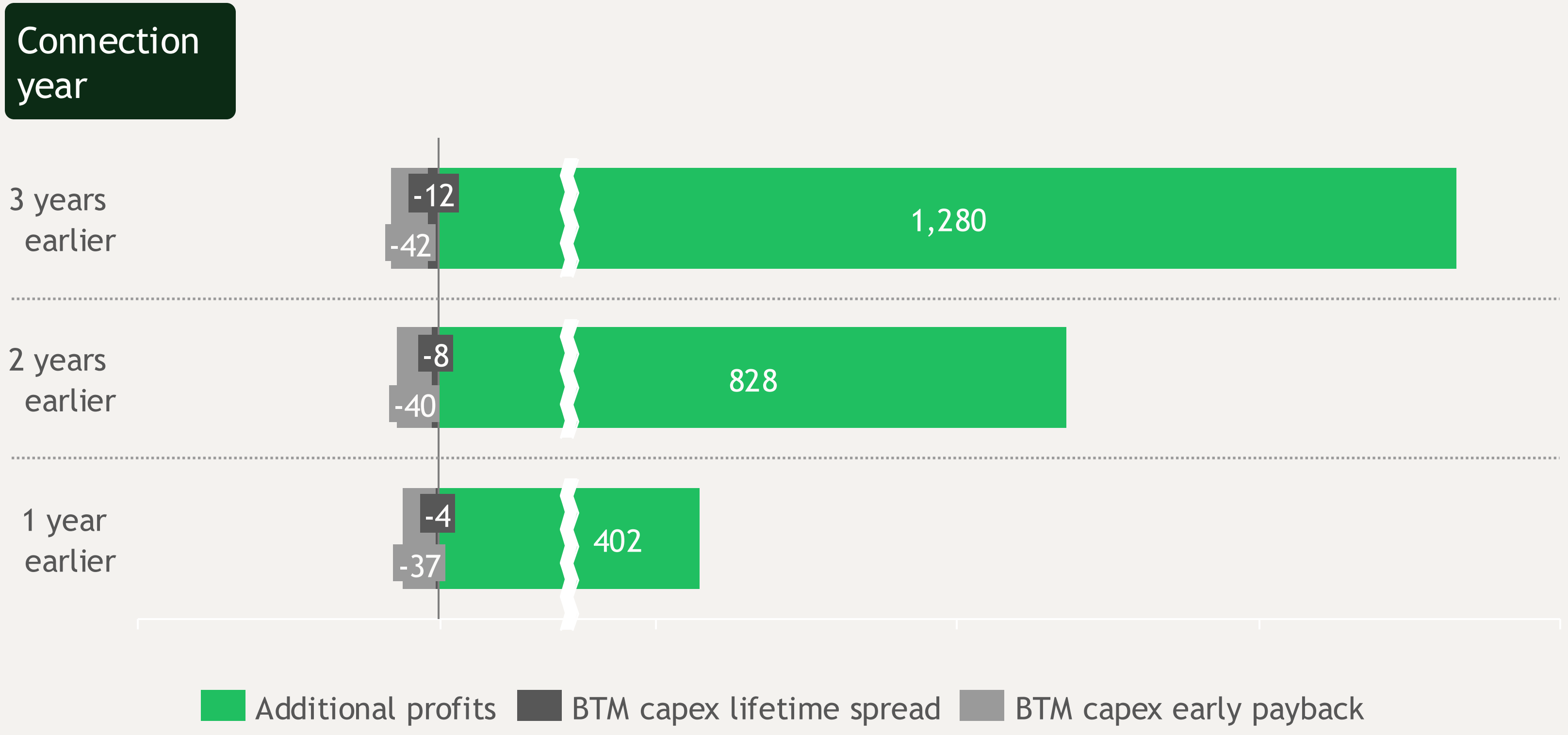


Source: BCG's DC BTM Optimizer.
1. Baseline is the scenario in which DC has a firm grid connection, and does not benefit from compute flexibility nor BTM assets.

Result: This adds costs to the data center's power supply, but in many cases their speed-to-power benefits outweigh these costs

Cumulative present value of earlier energization via non-firm grid connection

Illustrative for a 150 MW AI inference data center in NW-Europe in 2030, in $M



Non-firm connections bring energization forward by >1-3 years, unlocking profit that would otherwise be deferred

Operational flexibility and BTM assets ensure full compute demand coverage

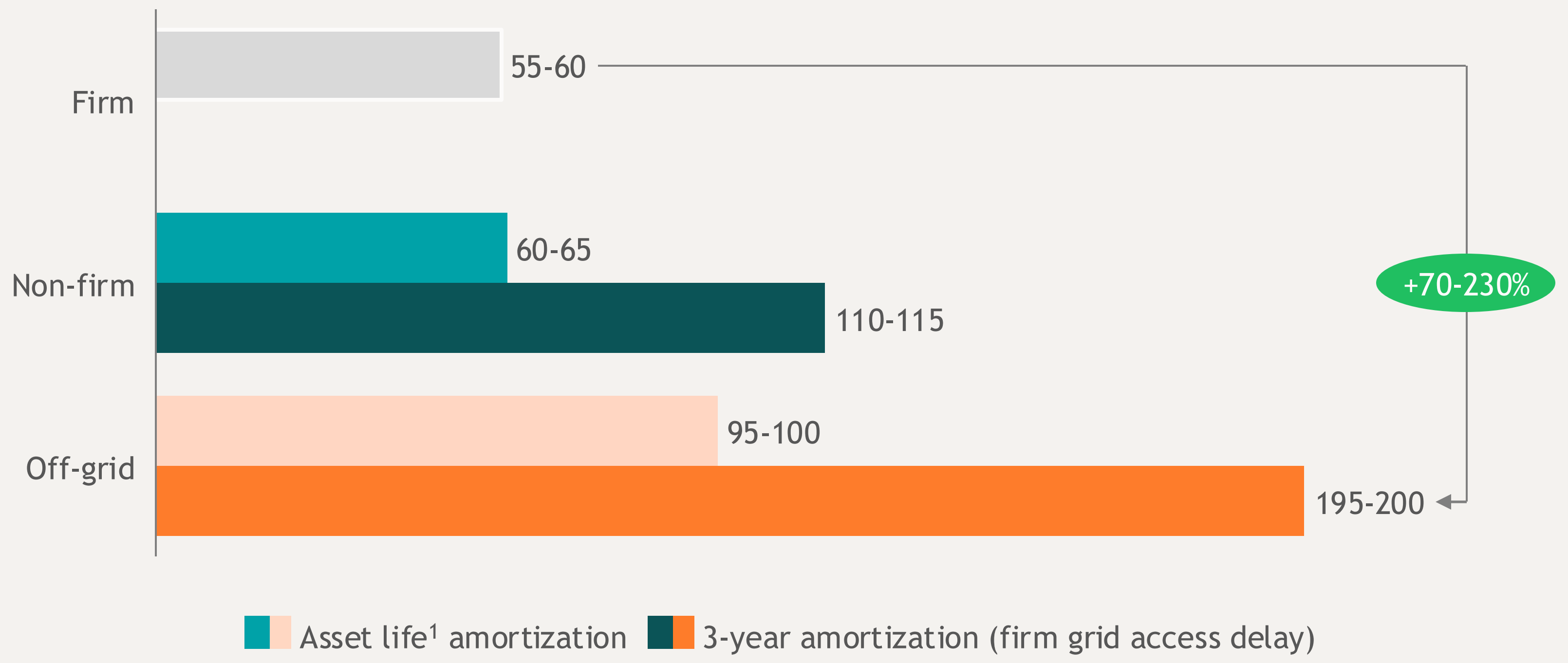
This prize depends on compute revenue, but even at lower levels the business case would hold

Adds real operational complexity: orchestrating BTM assets against grid signals, managing operational flexibility without breaching SLAs, siting and securing on-site BTM capacity for on-time energization

Source(s): BCG's DC BTM Optimizer; BCG analysis.
Note: Profits measured as EBITDA, including energy opex. BTM capex based on incremental BTM capacity versus a firm DC with BTM optimization, with assets sized to both close unmet demand and minimize total power supply costs. Early payback assumes BTM asset capex paid back during the earlier energization period. Lifetime spread assumes annualized BTM capex over the asset lifetime. Using a 6% WACC. Assumes DC annual revenues of ~$7M/MW, non-energy opex equivalent to 45% of revenue. Energy opex excludes network charges, taxes, and levies.

Result: These additional costs go up with the severity of the non-firm grid constraint, with off-grid adding 70-230% of costs

Annual power supply cost, excluding grid tariffs, taxes, and duties
Illustrative for a 150 MW AI inference BTM Optimized data center in NW-Europe in 2030, in $M/y



The severity of the grid constraint determines the BTM set-up and related extra power supply costs

In the extreme case of "off-grid" this adds ~70-230% to annual power supply costs, pending over what period the BTM assets are amortized (their lifetime or just the bridge to grid connection)

Already real where gas is cheap: Some developers build off-grid gas-powered data centers on pipeline supply, skipping queues

Our take: Relevant as a bridge where non-firm connections aren't available, or where even they would trigger large system costs

Source(s): BCG's DC BTM Optimizer; BCG analysis.
Note: Assumes 50% capacity reduction during 10% of the year for non-firm connections, WACC of 6%, and gas prices of $8.8/MMBtu.
1. Asset lifetime as follows: ~20 years for batteries, ~30 year for wind and solar, and ~25 years for gas turbines.

What each stakeholder can do to unlock grid-positive data centers

Data center operators

Why it matters

Non-firm connections advance energization by years, and can be overcome with the right on-site BTM optimization

What to do

- Steer siting towards less congested areas
- Pursue non-firm connections in case firm grid connections take too long
- Size on-site assets to operational flexibility and severity of grid constraints

Grid operators

Why it matters

Queues hold back new loads that could help repay the existing grid, and for which the grid is being expanded

What to do

- Steer siting toward locations with network headroom
- Make non-firm connections part of the standard offering, not an exception
- Consider flexibility as an alternative to grid reinforcement

Utilities

Why it matters

Utilities and BTM providers are uniquely positioned to help data center operators manage the world of energy

What to do

- Offer co-siting on land with existing power assets
- Tailor BTM offering to type of data center and location
- Anchor pitch on "time-to-power", not "cost reduction"
- Design for peak avoidance and congestion relief

Policy makers

Why it matters

Connection speed captures data center investments and shapes AI competitiveness, while lowering grid users' bills

What to do

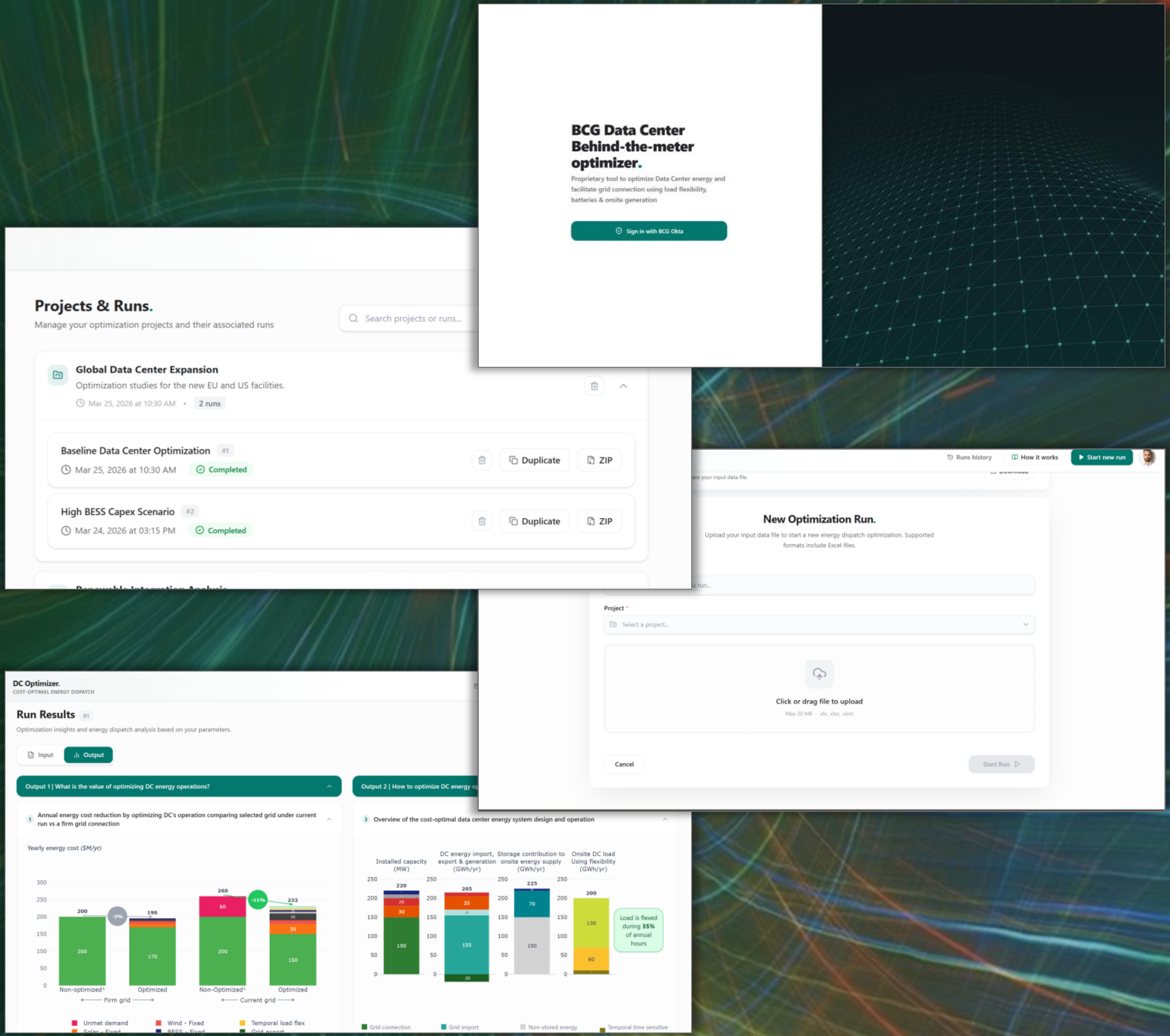
- Develop a national data center strategy
- Steer location decisions, enable non-firm connections, and facilitate on-site BTM
- Ensure gas grid operators are part of the strategy, given knock-on gas infra needs

Source(s): BCG analysis.

Methodology

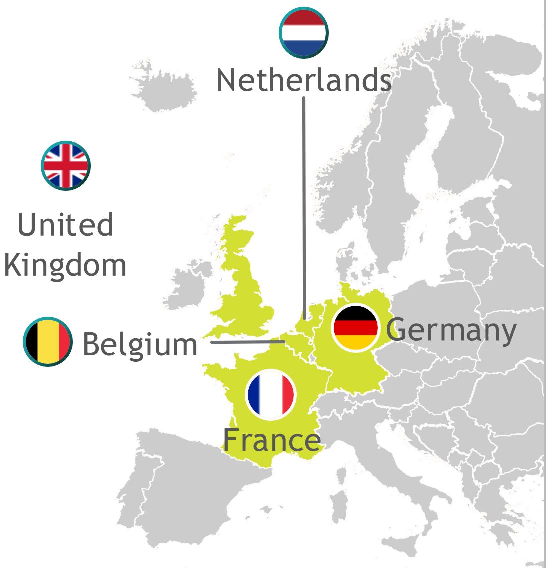
BCG developed a DC BTM Optimization model

The model jointly optimizes load flexibility, BTM assets, and interaction with firm versus non-firm access to determine the least-cost way to serve compute demand under different market and grid conditions



We applied the model across five NW-European markets, the 2030–2035 investment window, and different workload types

Markets



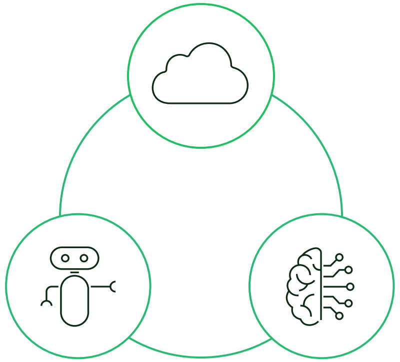
Timing

2050
2045
2040
2035
2030
2026

Focus on upcoming window of DC investments

Data Center Types

Cloud-focused



AI training-focused

AI inference-focused

Operating at a 65-80% utilization rate and varying levels of less-time-sensitive compute[1]

BTM Optimization Levers

- Load-shifting
- Gas Turbine
- Battery
- Solar Panel
- Wind Turbine
- "Virtual Flex"[2]

Source(s): BCG analysis.
1. Less time-sensitive compute refers to workloads that can be flexibly scheduled without significant impact on performance or customer experience (e.g., model training requests) 2. Sourcing demand-side flexibility from neighboring industrial facilities, such as adjusting their production schedules. Rather than curtailing data center (DC) operations to meet grid signals or contractual obligations, the DC effectively "borrows" flexibility from partners nearby and compensates them for it, achieving the same net effect on the grid without disrupting the DC's load profile.

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