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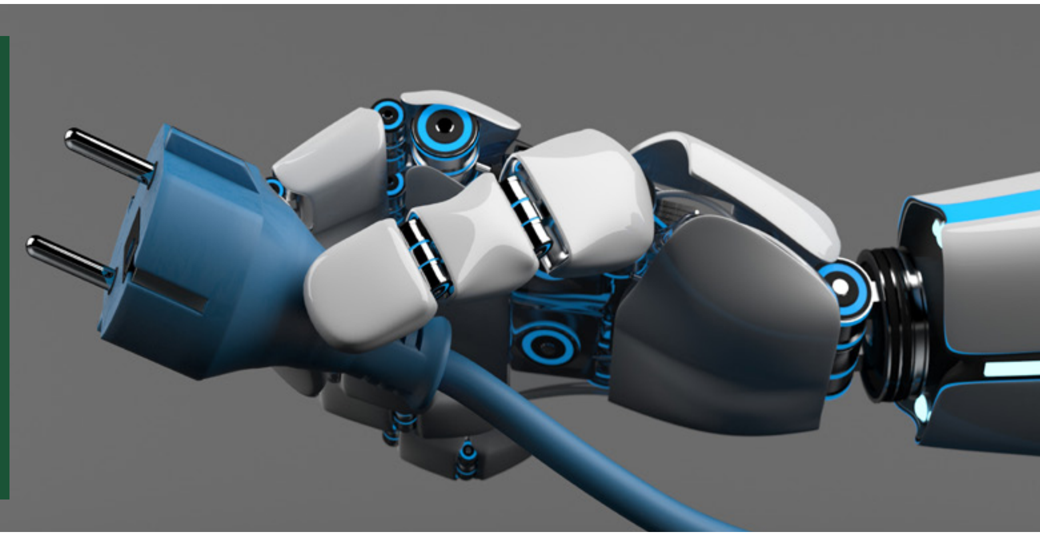


AI and Electricity Demand: The Very Hungry Caterpillar

William W. Priest, CFA
Vice-Chair, TD Wealth; Chairman of the Board of Directors, TD Epoch

Kevin Hebner, PhD
Managing Director, Global Investment Strategist, TD Epoch

Michael Jin, CFA
Managing Director, Portfolio Manager and Senior Research Analyst, TD Epoch

With contributions by:

Juliana Faircloth, CFA
Vice President, Portfolio Research, TD Asset Management Inc.

Carl Elia, CFA
Vice President & Director, Global Infrastructure Investments, TD Asset Management Inc.

Tim Yang, CFA
VP TDAM, Portfolio Research Manager TDAM Commodities

AI is a highly disruptive, general-purpose technology (GPT) with compute requirements that are likely to continue growing exponentially well into the 2030s. One consequence is that we are in the early innings of an electricity demand surge, especially when we add into the mix the rising share of electric vehicles and the onshoring of manufacturing facilities. This has critical implications for energy infrastructure investment, especially as the AI-induced boom follows an extended period (2007-2022) in which U.S. electricity consumption was flat.

AI models possess a seemingly insatiable "thirst" for electricity. To illustrate, between 2020 and 2022, annual electricity demand from four of the tech giants grew 58%, to an astonishing 90 terawatt-hours (enough to fully power 6.3 mn homes for a year). Most of this surge was driven by data center (DC) build, with one of the companies alone currently adding a new DC roughly every three days. DCs are power-hungry beasts, and we expect their overall electricity demand to triple over the next decade.

The electricity demand boom will stress existing infrastructure, including generation capacity, transformers, and the transmission and distribution (T&D) grid. Without massive investment, as well as transformational innovations (for example, regarding battery storage, small modular reactors, and less heat generative semiconductors), there is a rising risk that electricity demand races ahead of supply. This could create a chokepoint that impedes AI progress, with negative consequences for innovation, productivity, national security, and equity markets.

This paper is the fifth in our series on AI and consists of seven sections:[1]

1) Why is electricity load growth increasing now, after having been flat from 2007-2022?
2) Will power supply constraints impede AI progress?
3) Why is our infrastructure so old and why does it take so long to build capacity?
4) Is AI unwelcome news for CO_2 emissions and climate change?
5) The key risk: Enormous uncertainty about future electricity demand.
6) What does the boom in electricity demand mean for commodities markets?
7) Implications for investors: For utilities, companies exposed to electricity infrastructure, and infrastructure investments.

[1] Our first three AI-related papers examined the implications for the labor market, productivity growth, and the regulatory environment, while the fourth asked if we are already in the midst of an AI bubble.

1) Rising electricity demand: Scale is a critical driver of AI performance

We are still in the early days of AI diffusion, analogous to where the internet was in 1995, the PC in 1980, or electricity in 1900. This is important because tech companies worship at the altar of scale—the creed that throwing more compute and data at an AI model is the best way to improve performance. To illustrate, the compute used to train individual AI models has been increasing exponentially over the last fifteen years **(Figure 1)**. For example, GPT-4 (released March 2023) is estimated to have been 100 times more demanding to train than its predecessor, GPT-3 (June 2020).[2]

Training a foundational AI model requires an enormous amount of compute and hence, electricity. However, that is not the end of the story as inference is also power hungy and becoming ever more so. To illustrate, a traditional search engine query requires about 0.3 watt-hours (Wh). However, a comparable GPT-4 request would necessitate 2.9 Wh, a roughly ten-fold increase.

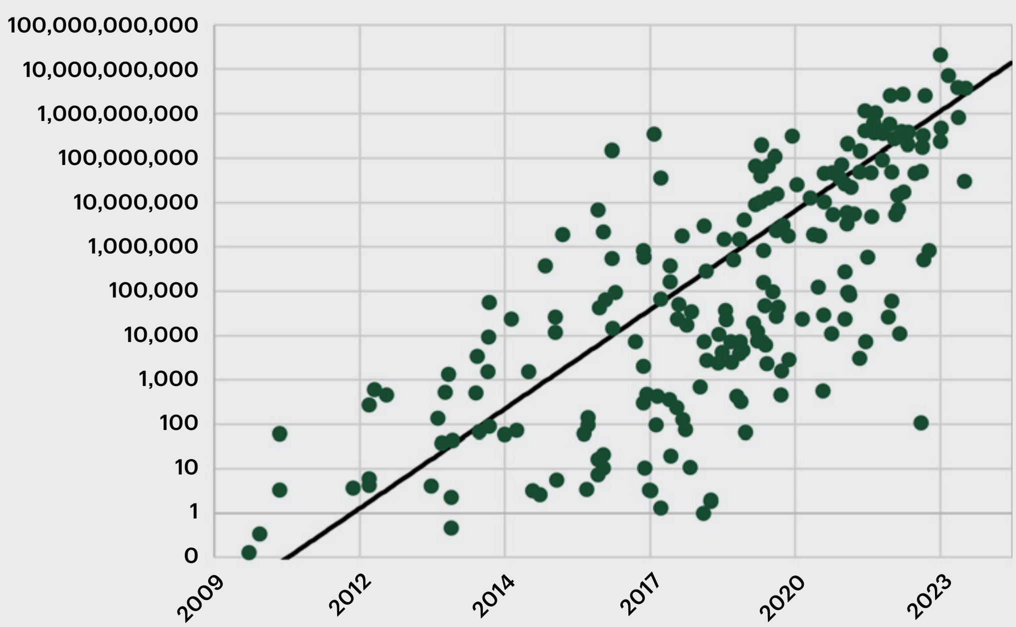
According to SemiAnalysis, if every search engine search was implemented using a large language model (LLM), it would command an additional 80 gigawatt-hours (GWh) daily or 29.2 terawatt-hours (TWh) yearly of electricity consumption. While this represents a staggering amount of electricity, it is only a taste of things to come. Future use cases for AI will increasingly emphasize compute-intensive capabilities such as image, video and sound generation which consume multiples more energy **(Figure 2)**.

Data centers: A CAGR of 12% over the next decade, driven by AI

Having demonstrated the criticality of scale to AI and how inference is set to become progressively more compute intensive, we now examine the outlook for DCs and what that means for electricity demand. The International Energy Agency (IEA) reports there are currently more than 8,000 DCs globally, with about 33% of these located in the U.S., 16% in Europe and 10% in China. Further, construction of U.S. DCs was up 25% last year (according to real estate firm CBRE) and the market size of DCs is projected to maintain a double-digit growth rate **(Figure 3)**.

Figure 1: Computation used to train notable AI systems (measured in petaFLOP, log scale)

The amount of compute has been increasing exponentially with no signs of slowing down



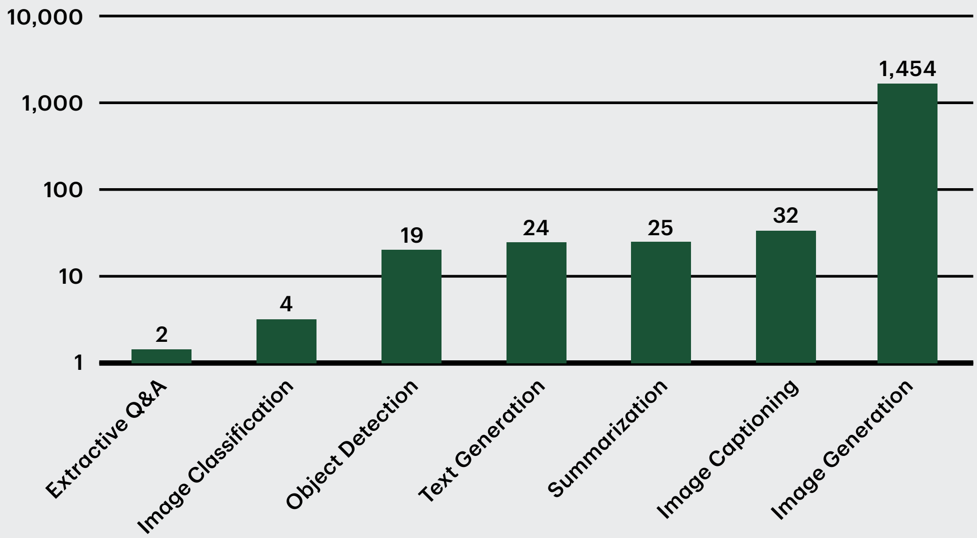
Source: Our World in Data

Note: A petaFLOP is 10^{15} (a quadrillion) floating-point operations. Examples of single floating-point operations are 15.2+3.74 or 97.8/6.453. Training OpenAI's GPT-4 required 21 bn petaFLOP, a number of mathematical operations that would keep your iPhone 12 busy for roughly 60,000 years.

[2] The CEO of a popular AI research organization, indicated recently that they will release an "amazing model this year," representing as big an advancement as GPT-4 did, with a commensurate leap in compute requirements.

Figure 2: A picture is worth a thousand words — Inference energy used for various tasks (as a multiple of energy for a simple text classification, log scale)

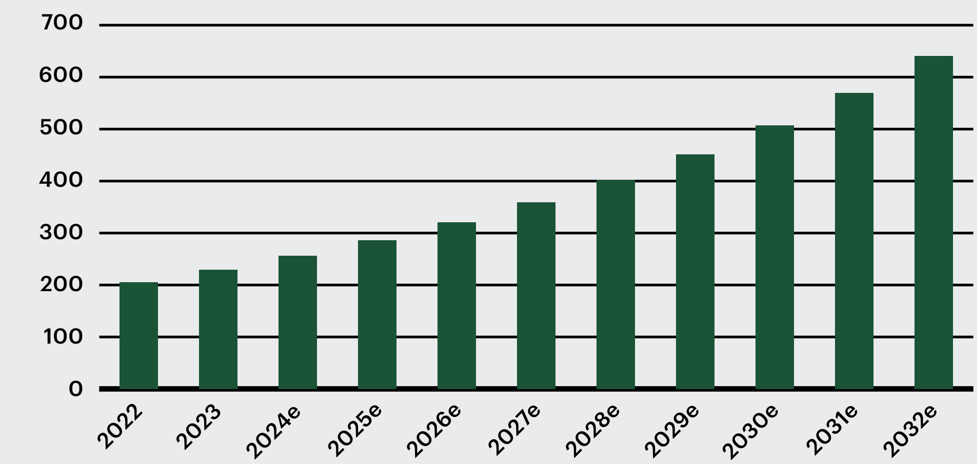
Generating images requires more than 1,000 times the energy of text classification.
The energy demands of sound and video generation will be thousands of times greater still.



Source: "Power hungry processing: Watts driving the cost of AI deployment?" by A. Luccioni et al, Hugging Face and Carnegie Mellon, 2024

Figure 3: Global DCs, forecasted market size (USD bn)

The global DC market size is expected to increase from USD 230 bn in 2023 to USD 640 bn by 2032, representing a CAGR of 12.1%



Source: Bloomberg Finance, L.P.

As DCs proliferate and become increasingly compute intensive, their electricity exigencies will grow at a rapid clip, with the hyperscalers all looking to put GWs of additional demand on the grid. To illustrate, the Electric Power Research Institute (EPRI) estimates that U.S. DCs currently consume about 100 TWh/year with this increasing to 300 TWh/year by 2030.

Most importantly, there is an almost comically wide band, 150-510 TWh, around the EPRI's point forecast. This tells us much about the intrinsic degree of uncertainty facing utilities and infrastructure companies (and their investors). Further, the EPRI forecasts DCs to consume 7.0% of U.S. total electricity generation by 2030 vs 4.0% today. Again, with a monstrously wide range, 5.0%–9.1%, around this projection. The massive uncertainty about future electricity demand is under-appreciated and represents a critical challenge for investors.

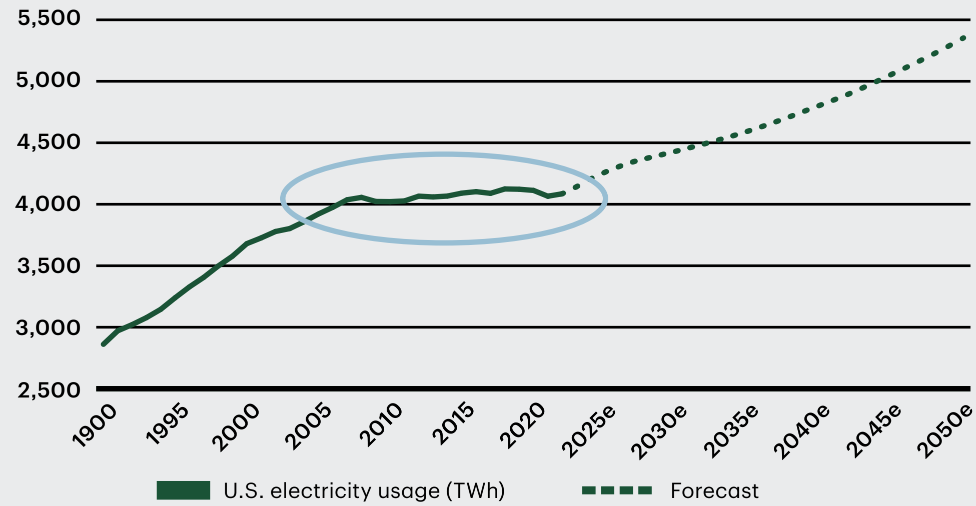
DC's ravenous appetite for electricity: The era of anemic demand is over

The above analysis demonstrates why commentators frequently refer to electricity as the lifeblood of the AI boom. Further, AI diffusion helps explain why U.S. utilities are faced with significant demand growth for the first time in decades **(Figure 4)**. Load growth exhibited a piddling CAGR of 0.4% in the decade ending 2022, but the U.S. Energy Information Administration (EIA) projects this to increase seven-fold, to 2.8%, from 2023-2030.

As a slight digression, we would like to emphasize that AI is not the only driver of increased demand for electricity. The IEA expects AI and DCs to represent about half the increase over the next decade, with the transition to EVs and the reshoring of manufacturing facilities accounting for roughly 30% and 20%, respectively. Regarding the latter, the objective of onshoring is to reduce supply chain vulnerabilities, an especially critical ambition for semiconductors, which is classified under computer and electronics **(Figure 5)**. The sharp break in this series occurred three years ago, reflecting increased geopolitical tensions, as well as the Chips and Science Act of 2022. Onshoring is an ongoing secular trend and constitutes an additional factor driving electricity demand growth.

Figure 4: Long-term U.S. electricity usage, with forecasts

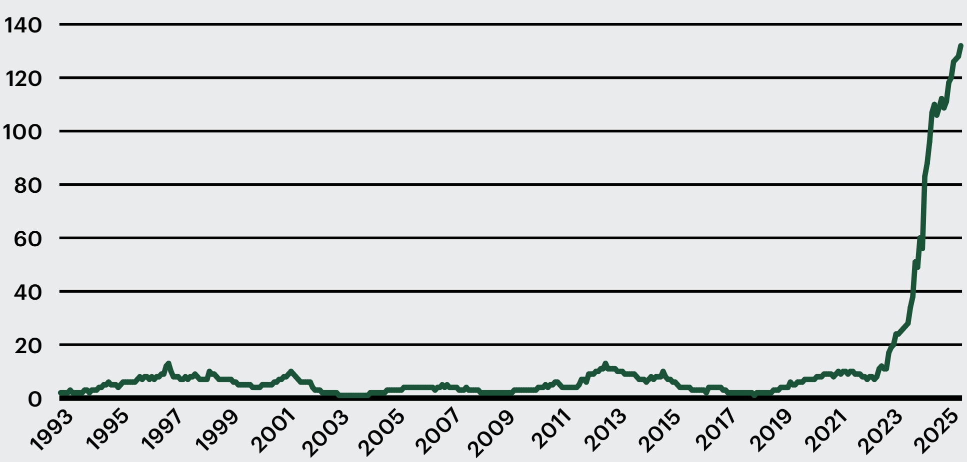
Electricity demand was flat from 2007-2022, but is now back on a solid growth trajectory



Source: EIA

Figure 5: Manufacturing construction — Computer and electronics (USD bn, saar)

Construction of such manufacturing facilities, primarily for semiconductors, is up an astonishing seventeen-fold over the last three years



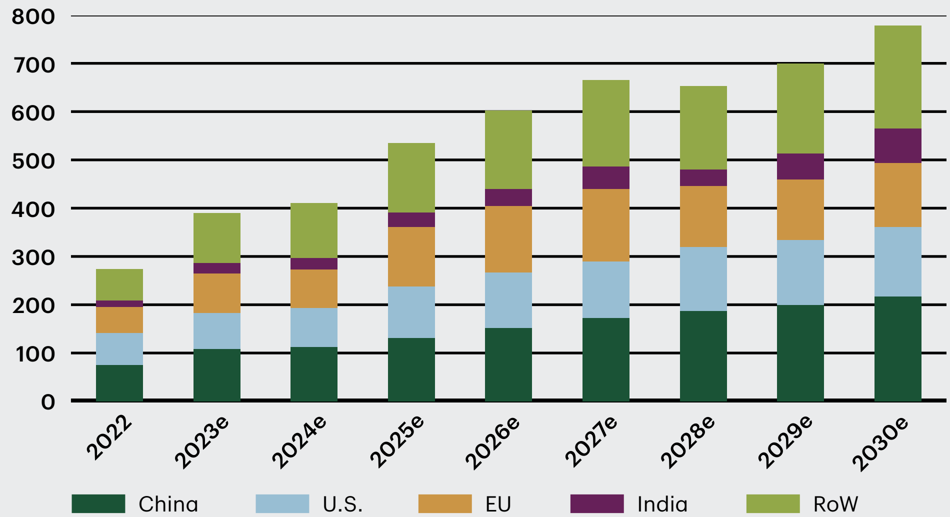
Source: U.S. Census Bureau

Electricity infrastructure: Massive investment is required

In response to the strong demand outlook, global investment in electricity infrastructure is expected to increase almost three-fold, from $274 bn in 2022 to $777 bn in 2030 **(Figure 6)**. China accounts for the largest share of this increase (28%), followed by the U.S. and Europe (both 16%), and then India (12%). As we discuss later, this creates a number of opportunities and challenges for investors.

Figure 6: Global electrical grid investment by region (USD bn)

With a CAGR of 14%, the total is set to almost triple from 2022 to 2030



Source: Bloomberg Finance, L.P.

2. Where bits meet atoms: Will electricity constraints impede AI progress?

AI can be thought of as a stool built with four legs: algos, data, compute, and electricity. The importance of the first three has been well established for decades, but the fourth is relatively new. GPTs, like the computer and internet, always require complementary innovations and, in the case of AI, breakthroughs in each of the four legs is required to accelerate progress. By corollary, lack of advancement in any one of the four would constitute a chokepoint, causing AI momentum to grind to a halt.

Will the lack of electricity capacity constitute such a roadblock? This strikes us as entirely plausible and offers a concrete example of where the fast-moving world of bits runs up against the world of atoms. Progress is inherently slower in the latter. Think of the time it takes to add generation capacity, affix transformers, or build out the T&D grid. Moreover, the world of institutions always responds at a glacial pace. To provide a couple examples, utilities are by design slow-moving regulated entities, T&D build inevitably faces not in my backyard (NIMBY) opposition and, without fail, nuclear power proposals confront well organized opposition and formidable regulatory hurdles.

Reflecting these realities, the consensus is increasingly worried about a looming power crunch. To illustrate, according to a recent survey by Barclays, 75% of respondents believe rising grid investment is a long-term secular trend. However, only a minority of those surveyed believe grid equipment capacity can keep pace and an even smaller minority expect T&D issues to be adequately resolved.

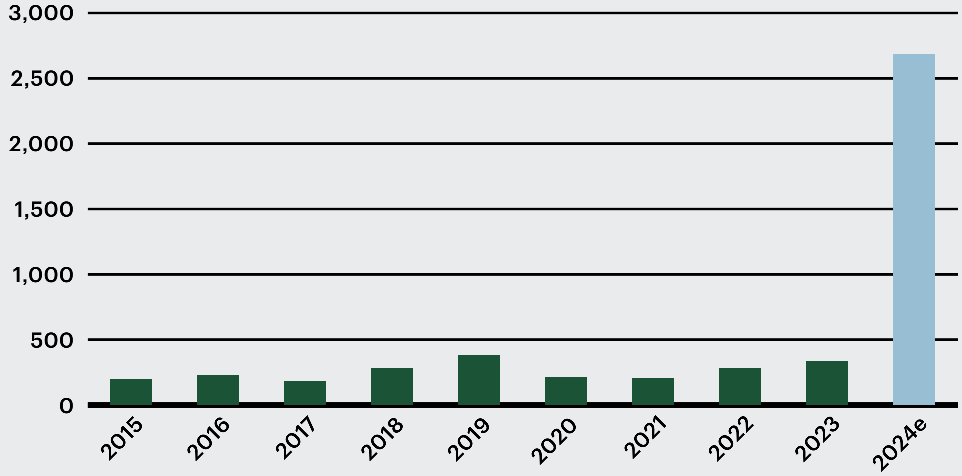
Still, there are two reasons to be a bit more optimistic. First, S&P 500 companies are finally discussing DCs and recognizing the broad opportunities implied by AI **(Figure 7)**.

Second, over the near-term, we believe electricity demand growth in most regions can be met with existing capacity. This is because regulators require utilities to offer total capacity well above estimated peak load (e.g., the hottest day in the summer). To illustrate, this "reserve margin" is currently 31 GW in Texas but is forecast to shrink from 2028 **(Figure 8)**. Regulators often require a 15% margin, which could become binding within a few years in several regions. Most electricity markets will tighten in this manner implying that, beyond the near-term, there will likely be capacity issues.

Regardless of companies new focus on DCs and the "reserve margins" required by regulators, the consensus expects increased grid congestion

Figure 7: Transcript mentions of "Data Center" by S&P 500 companies (ex-Tech and Real Estate)

After having been off the radar for decades, companies are finally talking about DCs

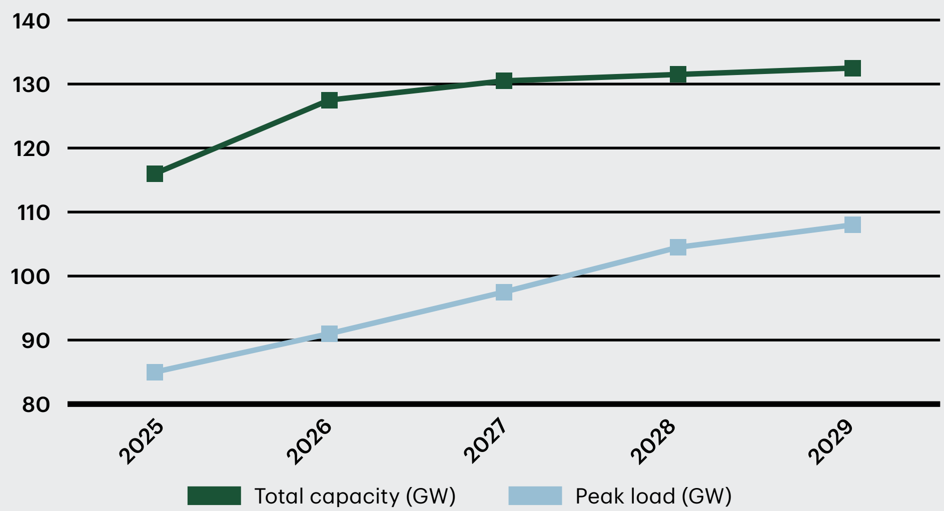


Source: Bloomberg Finance, L.P., TD Asset Management

Note: 2024e is annualized based on Q1 earnings season

Figure 8: Total capacity (GW) and peak load (GW) estimates for Texas during the next five years

"Reserve margins" are set to shrink which will put upward pressure on prices and heighten concerns about future capacity constraints



Source: The Electric Reliability Council of Texas (ERCOT), May 2024

and constrained electricity supply. That is, the U.S. will prove too slow in building the necessary electricity infrastructure, which would negatively impact AI progress.

To provide a specific example of the damage that is already being experienced, transmission congestion costs in the U.S. are estimated to have risen to $21 bn in 2022 (up during five of the last six years, surging 220% since 2016). Such costs are incurred when there is inadequate grid capacity to deliver the lowest-cost generation to consumers. Regulators top priorities are grid reliability (no blackouts) and low electricity rates for consumers. However, critics argue they do not sufficiently prioritize load addition and that the regulatory approval process remains far too slow.

According to Grid Strategies, a power sector consulting firm, "The best way to reduce transmission congestion is to increase transmission capacity. However, very little of transmission spending is on new large-scale, high-voltage transmission lines." Yet, the need for new lines continues to increase, reflecting three factors: rising electricity demand (due to AI, as well as EVs and onshoring), greater share from clean energy (often located far from customers), and extreme weather.[3]

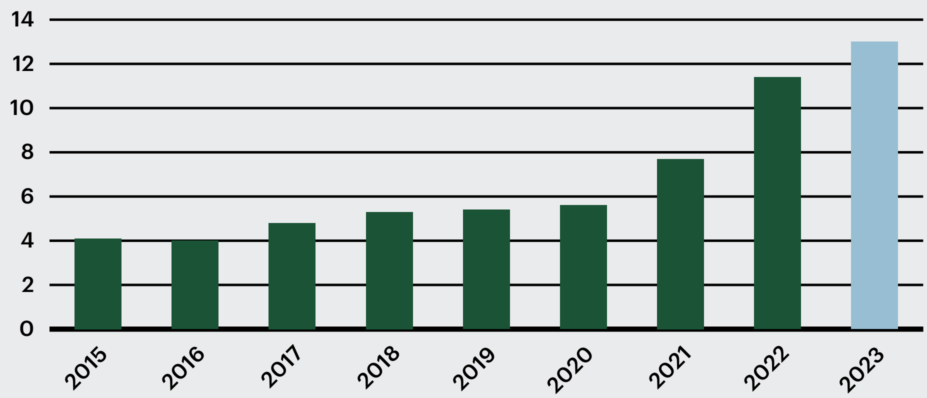
3. Why is our electricity infrastructure so old and why does it take so long to build capacity?

There is a widespread concern in America about the dismal state of overall infrastructure and the depleted capabilities of manufacturing across many sectors. More specifically, these worries also apply to aspects of electricity generation and the grid, including transformers and DC cooling systems. For example, industry observers claim it takes three years to deliver a voltage transformer, up from less than a year previously. Further, order backlogs at some energy infrastructure companies have tripled over the last few years **(Figures 9 and 10)**.

Three explanations have been offered for this situation. One is that it echoes the general hallowing out of America's manufacturing base that has occurred over the last three decades and impacted so many sectors (the "China shock"). This has also led to a dearth of skilled, experienced workers across numerous trades and occupations (including electricians and electrical engineers).

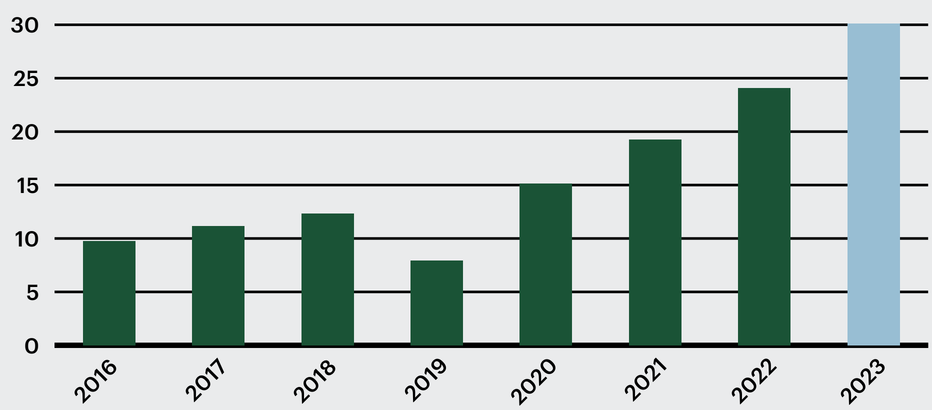
Figure 9: Backlog at an Irish/American multinational power management company (value, USD bn)

The order backlog has more than doubled since 2020



Source: Bloomberg Finance, L.P., TD Asset Management

Figure 10: Backlog at American infrastructure services provider (value, USD bn)



Source: Bloomberg Finance, L.P., TD Asset Management

[3] "Transmission Congestion Costs Rise Again in U.S. RTOs," Grid Strategies, July 2023 (RTO: Regional Transmission Organizations).

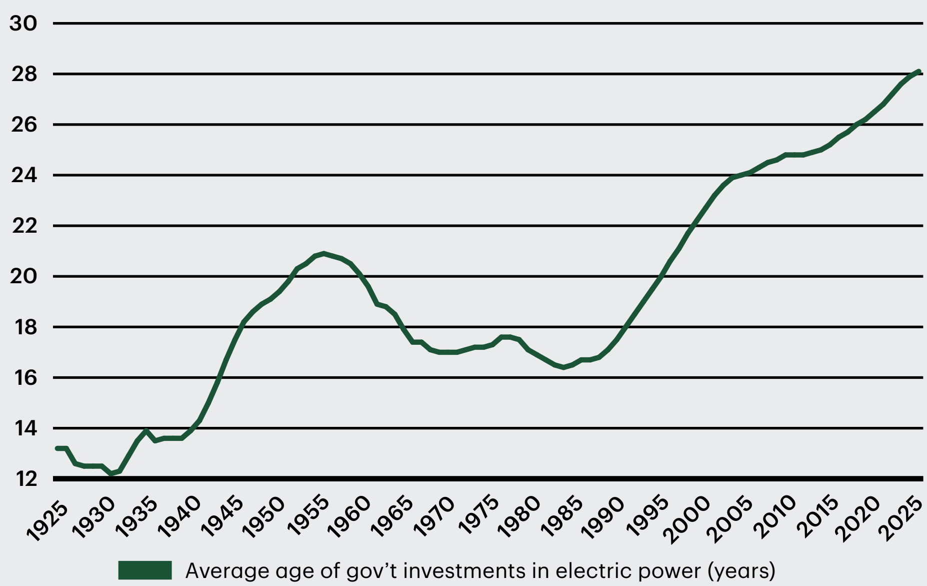
A second view is that companies extrapolated fifteen years of zero electricity growth into the future and, as a result, were caught flatfooted when load growth rebounded from 2022. This rings true as most employees of utility companies have never experienced a period of rapid growth in demand.[4]

A third part of the explanation lies with the decline and graying of investment in electricity infrastructure. In most countries, governments are major investors in electric power. However, the U.S. is an outlier with only 11% of power investment currently from the government (down sharply from 20% two decades ago and 25% in the early-1980s).[5] Further, 95% of that is from state and local governments, with the cash-strapped federal government investing precious little. Moreover, the average age of government investments in electric power is a geriatric twenty-eight years **(Figure 11)**.

The average age of private investments in electric power is also high relative to history, suggesting both neglect and significant replacement spending over coming years. This perspective is corroborated by the American Society of Civil Engineers which issues an "Infrastructure Report Card" every four years. The most recent report concluded that energy infrastructure merited an uninspiring grade of C-, emphasizing dramatic aging across generation capabilities and T&D: "The majority of the nation's grid is aging, with some components over a century old — far past their 50-year life expectancy — and others, including 70% of T&D lines, are well into the second half of their lifespans."

To expand on this point for a moment, the U.S. electric grid contains 642,000 miles of high-voltage transmission lines and 6.3 mn miles of local distribution lines (the "last mile"). This "backbone" of the electricity delivery system faces a major investment gap as the mileage of new high-voltage transmission lines (230kV and above) built annually in the U.S. is flat or declining.[6] This reflects skyrocketing costs and frequently, fierce resistance from local communities. The good news though is that T&D underinvestment has little direct near-term impact on DCs as they are generally able to locate facilities close to the existing grid. The bad news is that DCs, like other consumers of electricity, face a substantial risk of congestion and constrained supply in coming years.

Figure 11: Governments in the U.S. have neglected electric power since the mid-1980s



Source: U.S. Bureau of Economic Analysis

[4] Many utility companies redirected their capex from capacity expansions to grid resilience and modernization (such as smart meters and other "grid enhancing technologies"). Additionally, they have invested heavily in renewables power generation.

[5] The declining share of government investment in power reflects a broader trend. During the 1950s and 1960s, overall government investment represented over 6% of GDP. This declined to 4.5%–5.0% in the 1970s and 1980s, and has continued to ratchet down, so that it now sits at a historical low of 3.3%.

[6] In 2023, 1,251 miles were built, well below the 15-year average of 1,677 miles. This occurred despite annual transmission spending increasing from around \$10 bn in 2010 to roughly \$20 bn during recent years. This discrepancy reflects an unfortunate broader trend, the rising cost and declining efficiency of infrastructure spend.

4. Is AI unwelcome news for CO_2 emissions and climate change?

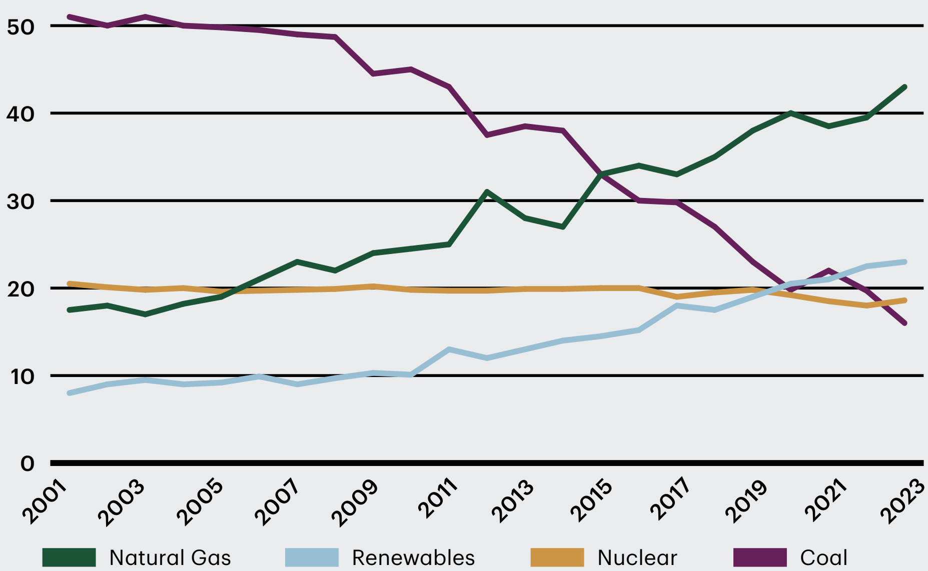
Unfortunately, there are four reasons to believe AI is bad news for emissions, at least for the next decade.[7] First, natural gas power plants are the best near-term solution to meet AI-driven demand growth, as they can be built quickly (under 24 months for a combined-cycle gas turbine plant). Further, such plants are highly flexible, meaning their output can easily be dialed up or down as demand fluctuates. This makes natural gas an ideal complement to renewables (which suffer from intermittency), to maintain grid stability. Further, the U.S. possesses abundant low-cost natural gas **(Figure 12)**.

Second, some coal plant closures might be delayed so that baseload growth can be met. However, this is just a temporary band-aid as utilities are determined to reduce their carbon emissions. Beyond the very near-term, the share represented by coal will continue to decline.

Third, wind and solar are increasingly important but, before they can play a dominant role in overall electricity generation, intermittency requires dramatic improvement in battery storage (from several hours to several days).[8]

Figure 12: The dash to gas — U.S. electricity generated by source (% share)

Natural gas and renewables will continue gaining share from coal, while nuclear's contribution has been remarkably stable for decades



Source: EIA

The share of nuclear has barely budged over recent decades

Although nuclear power is carbon free and has many fans, it has not represented a significant addition to U.S. generation capacity since the 1970s and 1980s. According to the EIA, nuclear added only 0.9% to America's overall generation capacity from 2016-2023 and is expected to add zero for the remainder of the decade. Moreover, when it comes to future plans, the U.S. has become a clear laggard relative to other countries **(Figure 13)**. This suggests we will need to rely on a combination of natural gas and renewables for at least another decade.

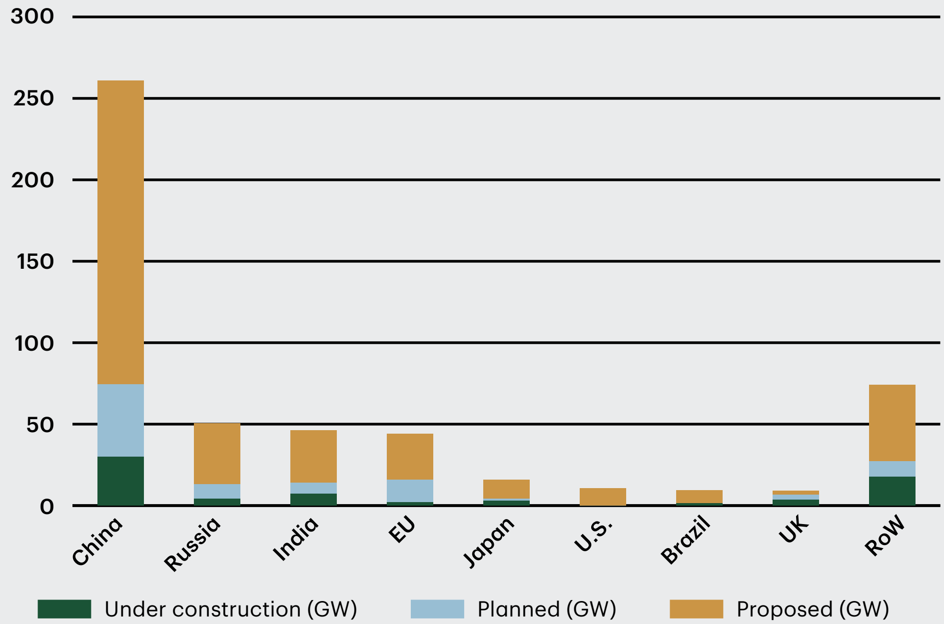
The demise of large-scale, conventional nuclear reflects a history of astonishing cost overruns and schedule delays, as well as (largely unfounded) safety concerns. It takes at least five years to build a facility, even if regulatory approval is instantaneous and there are no construction delays. And these are patently unrealistic assumptions given that we have largely lost the skills and capabilities required to both construct and regulate these complex projects.

[7] For example, a regional transmission organization, covering thirteen eastern states previously expected a 20% decline in CO2 emissions by 2030. However, faced with greater electricity demand, it now forecasts emissions to remain flat through the remainder of the decade.

[8] DCs — like manufacturing plants — require reliable 24/7 power which wind and solar do not provide. The good news is that battery storage is the fastest growing clean energy technology on the market, with global investment surging fivefold since 2018 (to $41 bn). As a consequence, the cost of a grid-scale battery storage system is plummeting (down 43% yoy in China). Source: "Batteries and Secure Energy Transitions," IEA April 2024.

Figure 13: Nuclear power projections (GW), by country

China holds a massive lead, while the U.S. is not expected to add capacity through at least 2030



Source: World Nuclear Association

Small modular reactors (SMR) are unlikely to be commercially available in the U.S. prior to 2030

Hopes run high for SMRs which are promising technologies and attractive in concept. In particular, proponents cite their (1) modular nature and scalability, (2) reliability and (3) location flexibility. The first feature is especially attractive to DCs.

However, new nuclear will take time. There are currently only four SMRs in operation globally (two in China, one in Japan and one in Russia), according to the International Atomic Energy Agency. The U.S. is again a laggard, albeit with seventeen in the design stage and two in early stages of progress. Moreover, given how novel the technology is, new SMRs may face engineering and project challenges, and could experience cost overruns and schedule delays similar to those with large conventional reactors. Although SMRs will not move the needle during the next decade, we are optimistic beyond that. However, the SMR industry will first have to prove it can deliver with reasonable costs and timelines.

Not just any power will do: The tech titans want theirs to be clean

Despite the negative implications of AI for carbon emissions, the big hyperscalers are serious about meeting clean energy commitments and exhibiting net zero carbon footprints. The tech titans prefer carbon-free electricity and can easily afford a price premium, which implies more renewables coupled with battery storage. While some degree of skepticism might be warranted, we largely take their net zero pronouncements both literally and seriously. Moreover, we believe they will commit massive capital to this space.

To illustrate, one of the tech giant's emissions were up 30% from 2020 to 2023, highlighting the challenges associated with meeting climate goals while building out DCs. In response, the company and a big infrastructure investor, announced on May 1 a groundbreaking $10 bn deal to build 10.5 GW of renewables capacity by 2030. The intent of the tech behemoth is to procure 100% of its electricity, 100% of the time, from zero-carbon sources by 2030.

As a second example, in March, another tech giant paid an energy company $650 mn for a 960-MW DC in northeastern Pennsylvania. This DC is directly powered by the adjacent Susquehanna nuclear power plant which, at 2.5 GW, is America's sixth largest and is licensed to operate through 2042 (it has been online since 1983). The company's explanation for the acquisition is that "we're on a path to power our operations with 100% renewable energy by 2025."

5. The key risk: Enormous uncertainty about future electricity demand

The consensus view calls for increased grid congestion and constrained electricity supply, and to some extent this has been getting priced into markets. However, we believe the key risk facing investors (as well as utilities and companies exposed to infrastructure) is the enormous uncertainty regarding future electricity demand.

There are critical uncertainties regarding technical progress (e.g., battery storage, SMRs, less energy intensive semiconductors), but the key unknowable concerns AI progress and how it proceeds along the S-curve. Earlier we cited the EPRI's estimate that the electricity consumption of U.S. DCs is set to increase from 100 TWh/year currently to 300 TWh/year by 2030. However, the most interesting feature of that forecast is the enormously wide band, 150-510 TWh, which tells us much about the inherent degree of uncertainty over the next few years.

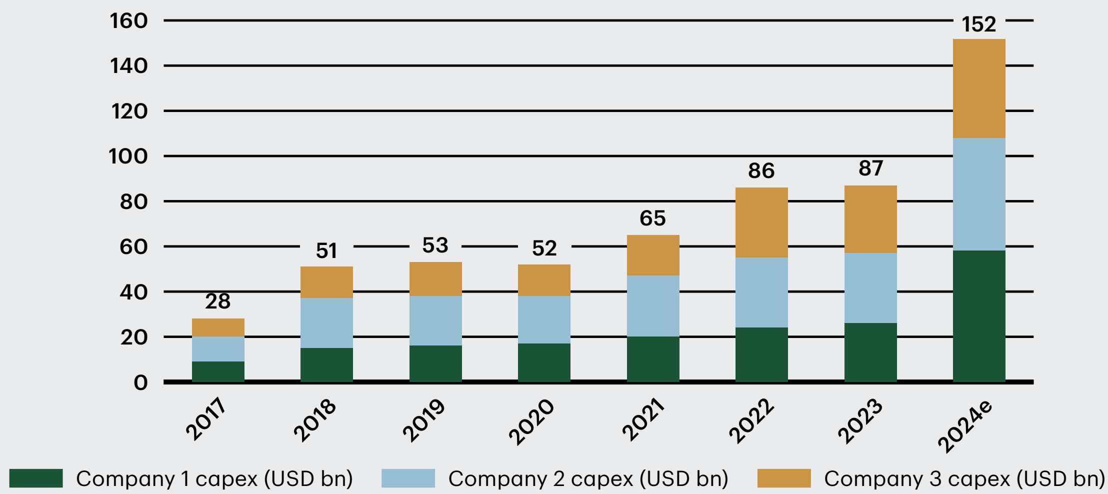
In light of such a wide band, what is the optimal investment path for utilities and infrastructure companies? There are clear risks to underinvesting, so should they assume 510 TWh? However, there are also major costs associated with investing too much, too early, especially if this ends up being yet another case of phantom demand. Further, there is significant risk of extreme volatility in DC build and electricity demand over the next decade.

In particular, the current capex boom by hyperscalers could prove to be unsustainable. The big three are forecast to spend $150 bn on capex this year with some commentators speculating that combined spending by 2030 could surpass $1 tn **(Figure 14)**.[9] Much of this infrastructure spend is on building, training, and deploying AI models, as well as acquiring DCs, servers, and networking equipment. This capacity will likely be required eventually but it could be a decade later than some pundits expect.[10] A boom-bust cycle would create havoc for utilities and infrastructure companies because hyperscaler capex is a leading indicator of DC-driven electricity demand.

There are three reasons to believe it might take longer for AI dreams to be realized and hence, the current capex boom turns to bust. First, the diffusion of GPTs always takes decades (as it did with electricity and PCs/internet). This is true even for AI, where the world of bits inevitably runs up against the world of atoms (and the world of institutions). Second, AI deployment will be regulated more than many think.[11] Finally, AI has not yet produced a killer app and we still have little idea of what that might look like. It could be many years before the big spenders earn a return on their massive capex outlays.

Figure 14: Capex by three tech giants (all USD bn)

No longer capital light – spending by the tech titans has increased more than fivefold since 2017



Source: Bloomberg Finance, L.P.

[9] To illustrate the eye-popping scale of these investments, the 13-year Apollo program cost a total of $120 bn and the 4-year Manhattan project cost $30 bn (both in today's dollars).

[10] This is what occurred with the 1990s tech wave as well as earlier bouts of exuberance, such as the British railway boom in the 1840s.

[11] See "Digital Empires: The global battle to regulate technology," by Anu Bradford, Columbia Law School, 2023.

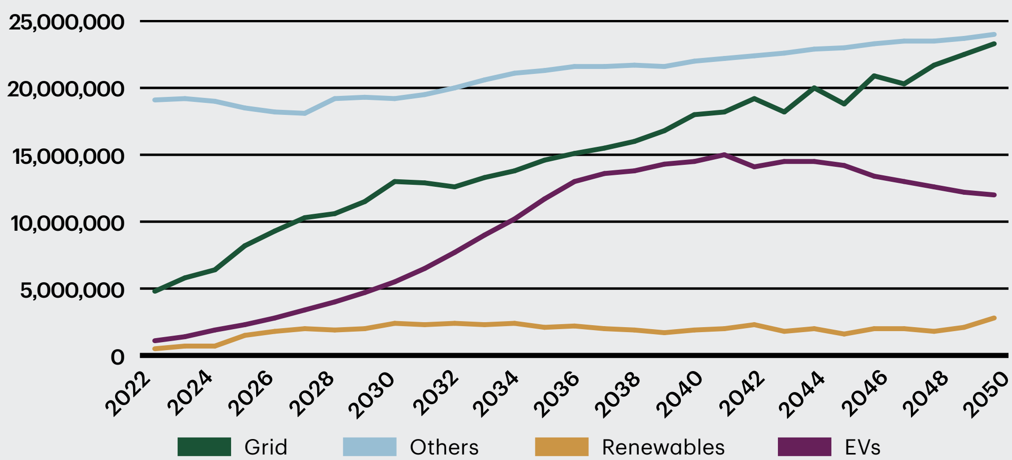
An important question for investors is then: How long will the hyperscalers' investment cycle last? We can never know for sure, but previous tech cycles lasted multiple years, suggesting we are closer to 1996 than to 1999. Certainly, there are few signs that AI exuberance is moderating. And if AI really is the next GPT, then we should expect investment intensity to remain elevated for even longer. In that case, the primary near-term risk is the consensus view mentioned earlier, that a lack of electricity capacity will constitute a chokepoint, slowing down AI progress.

6. What are the implications for commodities markets?

The impact of the boom in electricity demand on commodities merits an entire white paper, so here we will just provide a couple examples. For a start, the upgrading of the power grid, as well as the green transition, is beneficial for metals such as copper and aluminum **(Figure 15)**. To illustrate, grid demand for copper is expected to exhibit a CAGR of 13.2% to 2030 and then grow at a more moderate 3.0%. Moreover, we do not anticipate enough copper supply to meet demand beyond 2026.

Figure 15. Global copper demand by sector (metric tons)

Grid demand for copper is expected to more than double over the next decade, and then keep increasing, albeit at a slower pace



Source: Bloomberg Finance, L.P.

Another beneficiary is natural gas, at least in the near-term. As we discussed earlier, gas will continue to play a key role in electricity generation until renewables overcome several hurdles (intermittancy, which requires improved battery storage, as well as an updated power grid and improved access to refined industrial metals).

The demand for natural gas is driven by the delta between the growth of electricity demand (modelled by the increase in GDP and DCs) and the growth of renewables supply. This implies an almost 30% increase in gas demand by the end of the decade, with the bulk of that rise being driven by DCs. Further, although gas supplies are abundant, there are issues with its transmission, so expect increased capex in gas infrastructure and pipelines.

7. Implications for investors

In this section we highlight the implications of increased electricity demand for utilities, companies exposed to electricity infrastructure, and infrastructure investments.

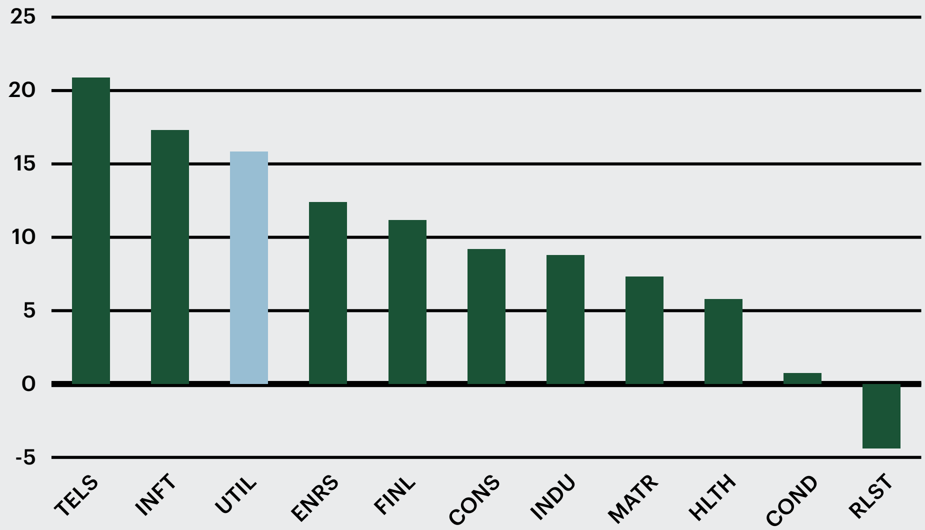
The increase in electricity demand has been great news for utilities

Utilities has been the third best performing S&P 500 sector year-to-date (YTD) **(Figure 16)**. The group consists of 31 companies, but three delivered especially outsized returns, ranking within the top ten performers YTD. All three are unregulated power producers that supply to DCs.[12] Their share prices have outperformed because they are able to immediately enter into long-term power purchase agreements and benefit from expectations that DC

[12] It is also worth mentioning that another independent power producer, is up 80% YTD. However, its market cap is too small to be included in the SPX. As discussed earlier, the company sold a data center campus for $650 mn in March.

Figure 16: S&P 500 sectors (% ytd, as of May 31)

Utilities is the third best performing sector ytd, trailing only communication services and tech, which includes the majority of the magnificent 7



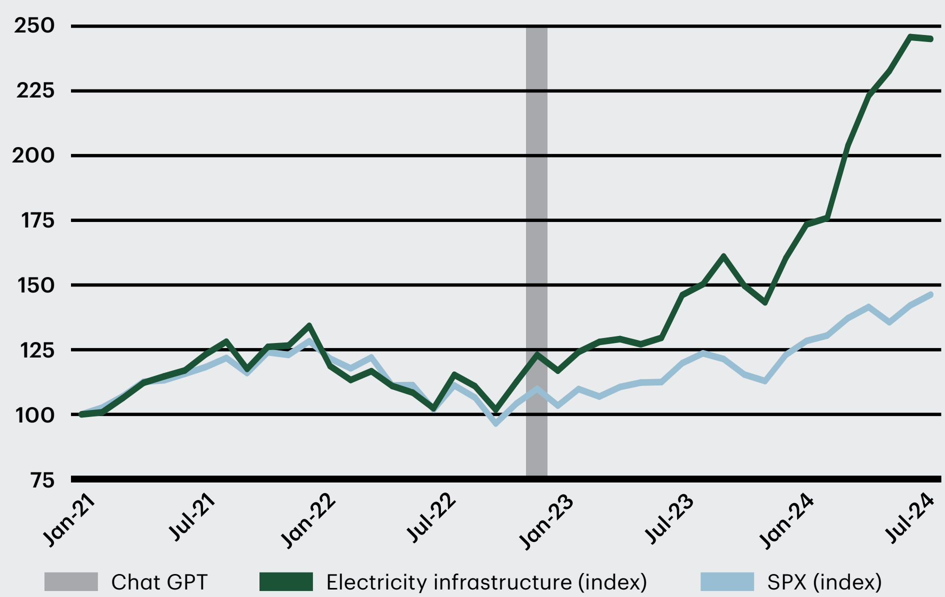
Source: Bloomberg Finance, L.P.

demand will drive up electricity prices. Most other utilities are regulated by state and federal commissions, which means they benefit less in the short-term from increased demand. While their shares have only experienced moderate gains YTD, they could still be significant beneficiaries in the medium-term.

Companies exposed to electricity infrastructure: Strong outperformance post-ChatGPT

We have constructed an electricity infrastructure index that is a market-cap weighted index of eight companies that are exposed to it **(Figure 17)**. Continued progress with AI could drive electricity demand even higher, resulting in further outperformance for this index.

Figure 17: Our index comprised of companies exposed to electricity infrastructure has dramatically outperformed the SPX since ChatGPT was released



Source: Bloomberg Finance, L.P.

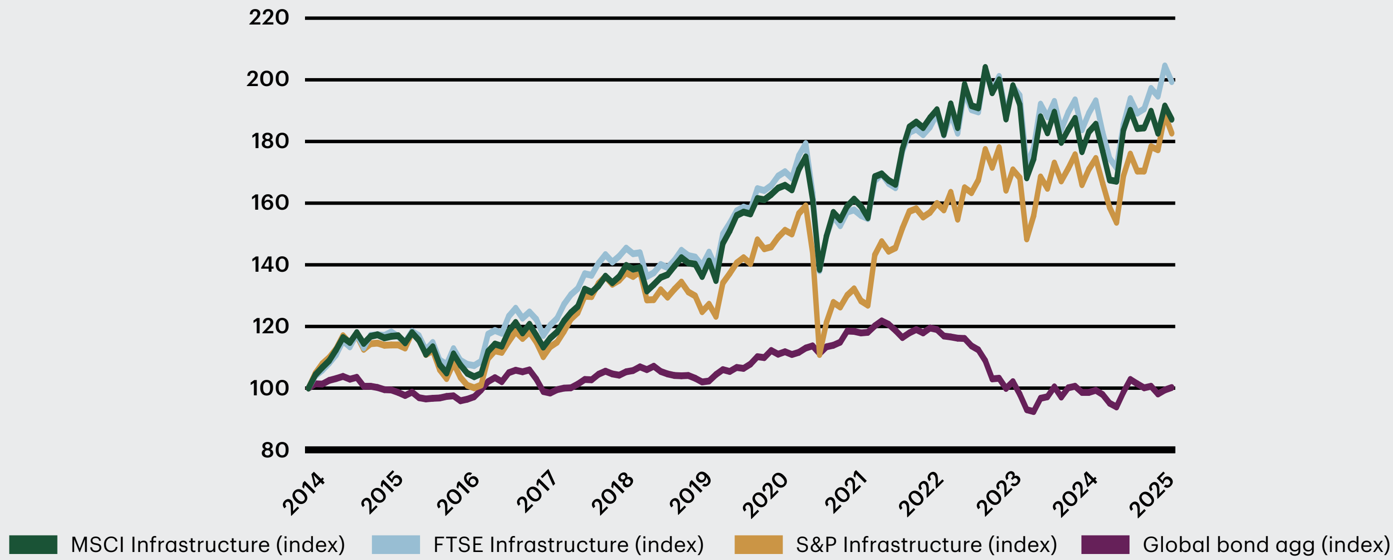
Infrastructure sector: Significant investment in power grids

The infrastructure sector has experienced exceptional growth in AUM since the global financial crisis (GFC) of 2008, which demonstrated the critical importance of having alternatives in a portfolio. More than a decade after the GFC, the COVID-19 pandemic reinforced that lesson: many alternative assets, including infrastructure, remained resilient amid the turmoil. We view the asset class as attractive because it has a relatively low correlation to equities, provides a hedge against inflation, and offers long-term, stable, risk-adjusted returns **(Figure 18)**.

Today, significant investment in power grids is occurring, resulting from the AI boom, the green transition and onshoring, as well as previous underinvestment. The requirement for both grid stability and low prices is driving growth in renewables, energy storage and other related assets. Further, the U.S. and many other countries have enormous need for new infrastructure and most governments are cash strapped. Overall, we believe the investment case for infrastructure has never been stronger.

Figure 18: Three global infrastructure indices (USD, index) vs the global bond aggregate index

Infrastructure indices offer a low correlation with equities, an inflation hedge, and have dramatically outperformed bonds



Source: Bloomberg Finance, L.P.

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