Goldman Sachs Research

Equity Research

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GS SUSTAIN

AI/Data Center Power Demand: The 6 Ps driving growth and constraints

As AI investment and legacy data demand continues to grow, we revisit our data center power demand outlook and the six drivers of upside/downside: **P**ervasiveness of AI, **P**roductivity of servers and compute, **P**rices of electricity needed to expand supply, **P**olicy initiatives, **P**arts availability to source varied types of generation, and **P**eople availability for infrastructure construction and maintenance. We see data center power demand (AI + non-AI) growth of 175% in 2030 vs. 2023 levels — the equivalent of adding a top 10 consuming country — up from +165% previously.

- Hyperscalers' healthy balance sheets, free cash flow, and corporate returns make rising supply cost of power — driven by market tightness and policy shifts — a less likely constraint in our view.
- We see parts and people as shorter-term drivers of power sourcing/availability, focusing capacity additions on renewables + natural gas peaking plants in the shorter term, natural gas combined cycle in the medium term and nuclear in the longer term.
- Pervasiveness of AI solutions will be critical for long-term demand and, in particular, demand elasticity to continued expected energy and compute productivity gains.

We continue to see Reliability of power/water as a multi-year investment theme amid rising demand growth, aging infrastructure and Adaptation to extreme temperatures/weather events. We continue to see attractive investment opportunities across the power supply chain driven by power demand growth acceleration — in the US, to levels not seen since the 1990s.

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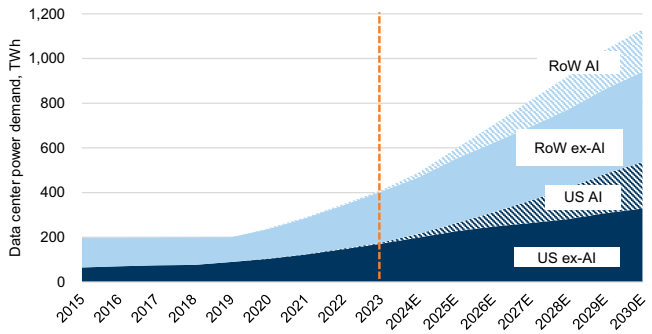
Key drivers/constraints to data center power demand and investment ideas across the supply chain

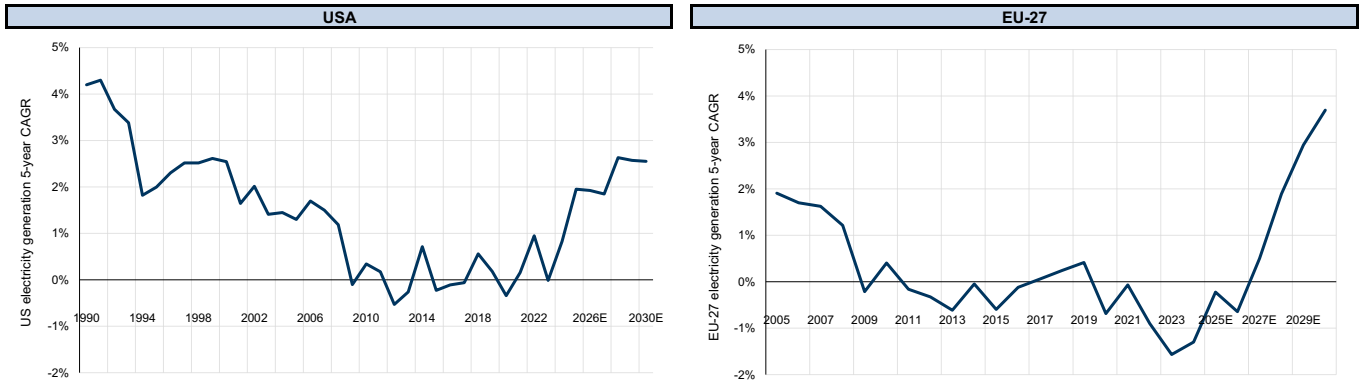
We now see global power demand from data centers — AI + non-AI — growing 175% in 2030 vs. 2023 levels, the equivalent of adding another Top 10 power consuming country. Our Utilities team expects the US contribution from data center power demand growth alone to accelerate US power demand growth through 2030 by 1.2 percentage points to an overall level of 2.6%, levels of which we have not seen since the 1990s. This acceleration has generated significant debate on whether power supply can meet actual or indicated demand. We believe the following 6 Ps will drive data center power demand: AI's **P**ervasiveness, AI compute and energy **P**roductivity, electricity **P**rices needed to expand supply, government **P**olicy incentives, **P**arts availability, and **P**eople availability for infrastructure construction and maintenance.

Exhibit 1: After being flat for 2015-19, we have seen data center power demand accelerate in 2021-23 and expect a ~175% increase through the rest of the decade
Global datacenter electricity consumption, TWh; includes AI and excludes cryptocurrency



Source: Masanet et al. (2020), Cisco, IEA, Goldman Sachs Global Investment Research

Exhibit 2: Generational Growth: Our Utilities Research teams expect USA and EU-27 electricity consumption accelerating through the end of the decade to levels not seen in 20+ years
5-yr CAGR for US and European electricity demand; forecasts from our US and Europe Utilities Research teams



Source: EIA, EMBER, Goldman Sachs Global Investment Research

Four key questions driving outlook for AI/Data Center Power Demand

1. Parts & People: Will equipment and labor availability constrain power

infrastructure? Equipment availability will be the principal driver of sourcing power capacity growth from renewables (in particular utility-scale solar and battery storage) and natural gas peaking plants in the near term, natural gas combined cycle in the medium term and nuclear in the long term. Our outlook for labor demand suggests the need for a substantive increase in skilled workers in transmission/distribution in the near to medium term.

2. **Price & Policy: Will power demand be constrained by rising supply cost of Green and non-green power options?** We believe Big Tech will continue to take an all-in approach to data center power sourcing, with continued willingness to pay Green Reliability Premiums while at the same time prioritizing time-to-market. We do not believe the sunsetting of Inflation Reduction Act incentives as part of the One Big Beautiful Bill Act will have a meaningful near-term impact on power sourcing.
3. **Productivity: Will new-gen AI chips and more efficient compute usage in the latest AI models drive lower or higher aggregate power demand?** We assume Big Tech cash flow/budgets will be the key constraint, leaving upside risk if there are no constraints and downside risk if compute speed or token demand are finite.
4. **Pervasiveness: Will AI server demand be constrained by AI results/innovations?** This will remain key to watch, particularly from a Sustainability perspective whether we see accelerated efficiency solutions in the health care, energy, agriculture and education sectors.

Investment opportunities across the power supply chain

While we continue to see a deceleration in annual global Green Capex vs. 2021-24, we believe what will remain prioritized are verticals:

- That maintain reliable power/water/energy supply amid aging infrastructure and more extreme temperatures/weather events.
- That are needed to meet rising power demand.
- That improve customer efficiency to reduce consumption intensity and mitigate inflationary pressures.

Pervasiveness & Productivity: Favorable outlook for long-term demand, even as AI's Energy and Compute Efficiency are likely to continue

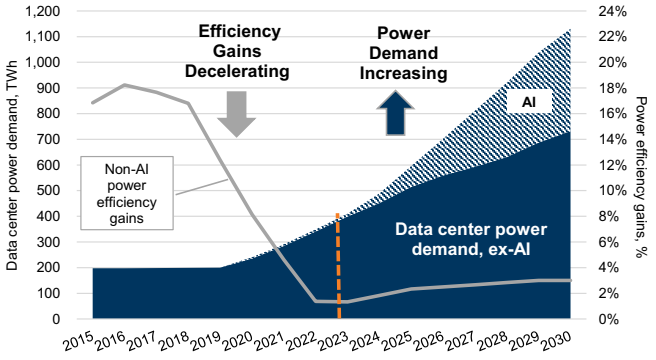
We see data center power demand rising 175% in 2030 vs. 2023 levels, a slight upward revision vs. our prior estimates (+165%). We update our data center power demand estimates to take into account the latest forecasts from our TMT and Telecom Services teams on AI server shipments and data center capacity buildout/vacancy rates. Upward revisions to in both demand (via increased server shipments) and supply (greater data center capacity) are driving our higher AI power demand growth, even as we raise our expectation for the pace of productivity gains for shipped server energy intensity. We also assume a slightly greater market share within AI power demand in the US, consistent with expectations for buildouts and vacancy rates from our Telecom Services team.

Over the longer term, we see the pervasiveness of AI, as well as continued growth of non-AI demand, as key drivers of power demand. In particular, we see two key areas of focus:

- The energy intensity and overall need for the inference phase. We continue to assume a lower energy intensity set of servers relative to the training phase, though the energy demands of inference are in some debate depending on the pervasiveness and innovations in reasoning and automation.
- The elasticity of compute demand to improvements in energy and compute intensity (i.e., will these efficiencies drive increased demand for tokens/compute?), or the Jevons Paradox. In past research, we have highlighted three scenarios — a demand constraint, when AI solutions are well delineated and efficiency gains in compute/energy drive little additional demand; a budget constraint, when efficiency gains drive increased demand without change to R&D budgets, and no constraint where efficiencies drive increased capital commitment. We assume the budget constraint at present, until there is greater confidence that AI solutions are broadly known and that corporate decisions to no longer invest incrementally in AI would not negatively impact competitive positioning.

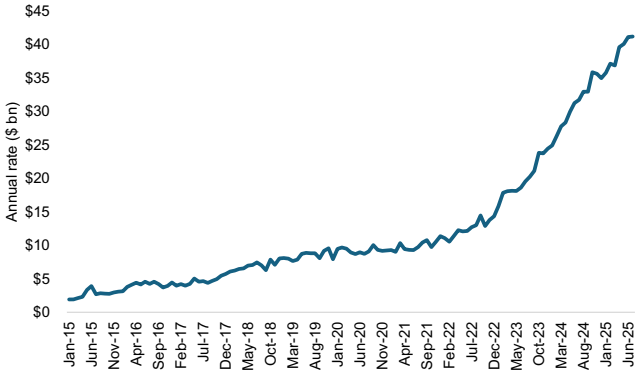
We use a slightly more conservative growth rate for non-AI (CPU) data demand driven by our Telecom Services team's Cloud/Hyperscaler non-AI outlook.

Exhibit 4: As efficiency gains have decelerated, data demand growth is driving a surge in datacenter power use, with AI acceleration expected to continue
Datacenter electricity consumption, TWh (LHS) and power efficiency gains ex-AI, % (RHS)



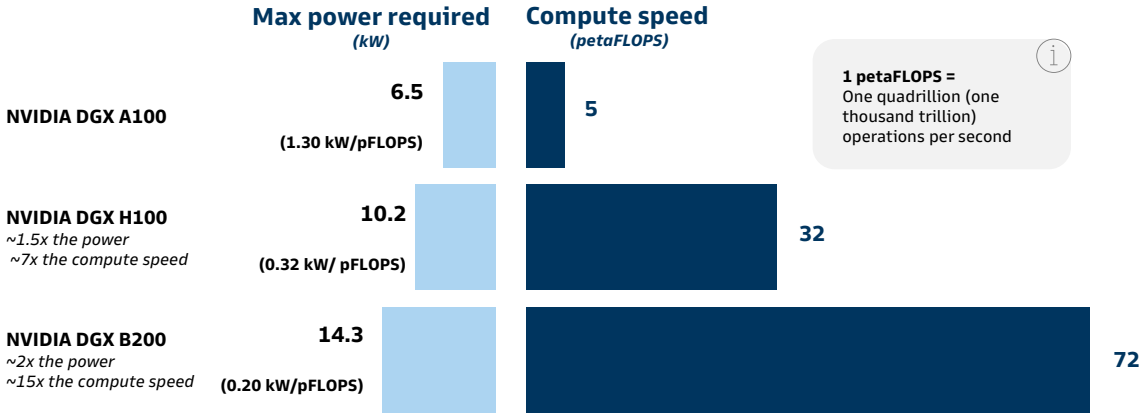
Source: Masanet et al. (2020), IEA, Cisco, Goldman Sachs Global Investment Research

Exhibit 5: After tripling over three years, annualized US data center construction spending has continued to grow to start 2025
Seasonally adjusted annual rates of US data center construction; $ bn (1/2014-7/2025)



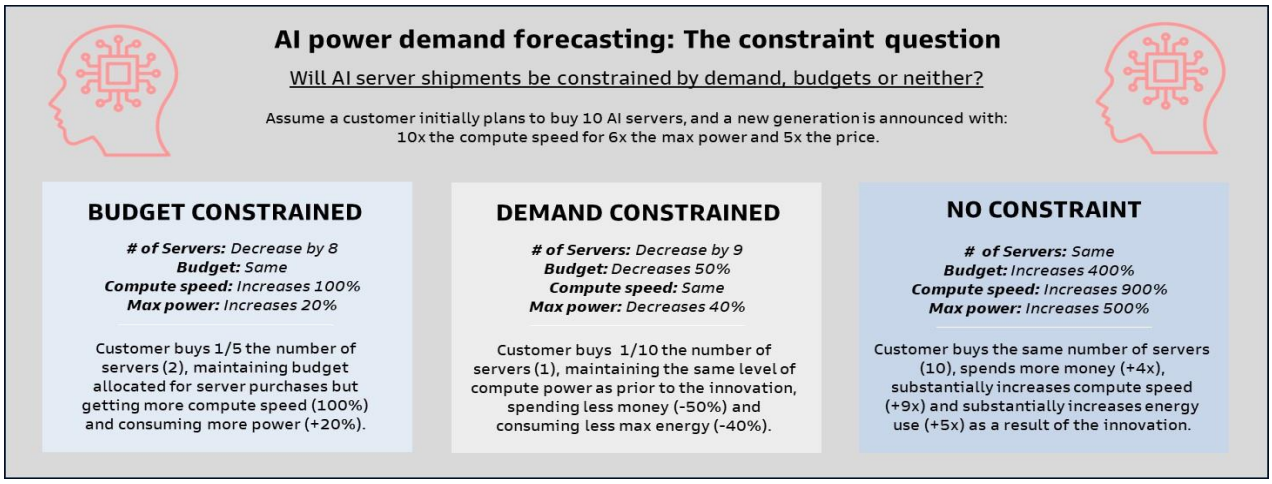
Source: US Census Bureau

Exhibit 6: We have seen new AI innovations increase max power consumption per server but increase computing speed per server by an even greater level, representing a meaningful reduction in power intensity
Recent evolution of NVIDIA server system specifications are indicative of increasing max power per server but with lower power intensity relative to computing speed



Source: NVIDIA, Goldman Sachs Global Investment Research

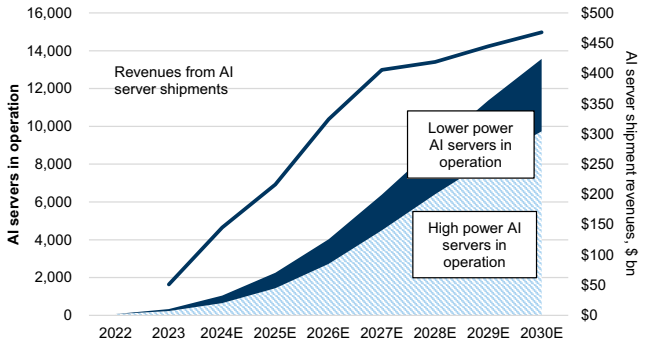
Exhibit 7: Extent of pent-up demand for AI server supply and voraciousness of technology capex budgets will be critical for pace of AI power consumption
Indicative scenario analysis of how demand vs. budget constraints could impact AI compute speed and power use



Assumes power generation, transmission and interconnection are not a constraint for indicative purposes

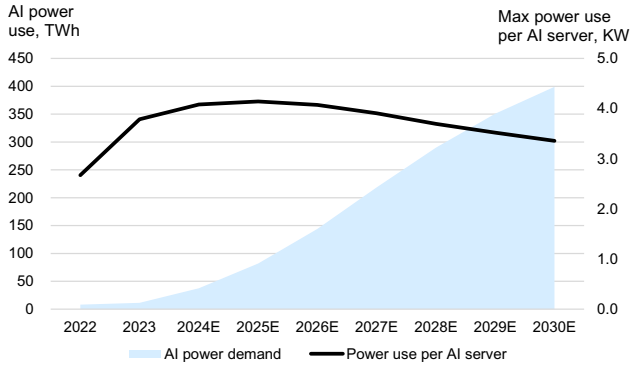
Source: Goldman Sachs Global Investment Research

Exhibit 8: Weighting of higher power vs. lower power AI servers, mix within high power AI servers of latest generation (more expensive, higher energy consumption, greater energy efficiency per server) vs. older generations and ultimate pace of AI server spending will be key to AI data center power demand
AI servers in operation implied by our global TMT team forecasts (LHS); implied annual AI server revenues (RHS)



Source: Goldman Sachs Global Investment Research

Exhibit 9: We see AI power demand growing rapidly even as power use per AI server falls later in the decade due to mix shift and expected efficiencies
AI power use, TWh (LHS); max power use per AI server, KW (RHS)



Source: Goldman Sachs Global Investment Research

Price & Policy: Rising power supply cost unlikely to be a constraint to data center demand

Pricing: We continue to view the Green Reliability Premium as relatively modest in the context of hyperscalers' EBITDA and strong corporate returns. While there is not a Green Premium to supply utility-scale solar or onshore wind to the grid in the US on average relative to power generated from combined cycle natural gas plants, we see a Green Reliability Premium for round-the-clock low-carbon solutions that have built-in redundancy to mitigate intermittency. The average Green Reliability Premium of the various low carbon solutions (without assuming a price on carbon) is about $40/MWh, based on our analysis. We do not believe this higher price point — or the $15/MWh increase we have seen in both gas-fired and renewable power solutions over the past year due to market tightness and policy changes — will be a constraint to AI/data center power demand. This is largely because hyperscaler balance sheets, free cash flow and corporate returns are strong.

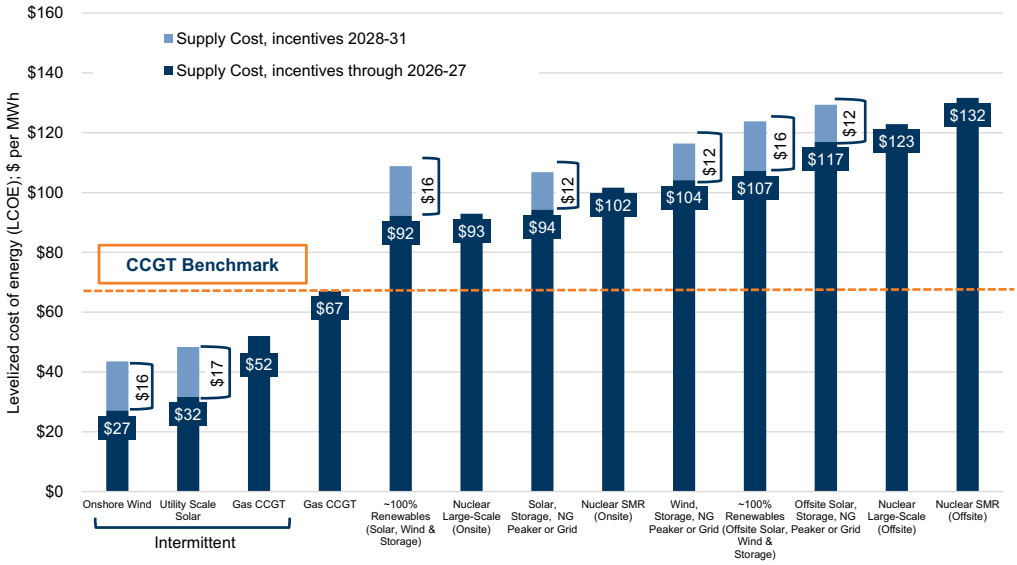
- If the 8 major hyperscalers were to pay an extra $40/MWh — consistent with the average US Green Reliability Premium — for all global data center power demand growth in 2030 vs. 2023, we estimate this would represent a cash outflow of $29-$34 bn in 2030. This is relatively modest in the context of hyperscaler total company EBITDA (2%-3% in 2027E) and corporate returns (1 percentage point impact vs. 30% average baseline estimates for cash return on cash invested; median across all sectors is about 12%-13%).
- When the Inflation Reduction Act renewables incentives roll off (post 2026-27 for projects not under construction, post 2029-30 for projects that are under construction now or will be before July 2026), our estimated impact of the $8/MWh higher Green Reliability Premium is also relatively modest for hyperscalers — 0.4% to EBITDA and 0.1 percentage point to corporate returns.

Because we do not expect these companies to be the sole drivers of data center power demand, the ultimate impact to these companies' returns if Green Reliability Premiums of this magnitude are supported is likely to be meaningfully less. **Additionally, we note that the Green Reliability Premium may be more modest in certain regions in the US as well as in other developed markets** that have higher local natural gas prices vs. our base case that uses $3.75/MMBtu Henry Hub gas. Green Reliability Premiums would also be otherwise lower in markets that have carbon pricing unlike the US with no federal carbon pricing mechanism.

Policy: Sunsetting of the Inflation Reduction Act incentives may impact sourcing at the end of the decade but is unlikely to have a major change in power capacity growth in the near term. We do not believe the sunsetting of the IRA incentives via the One Big Beautiful Bill Act (OBBBA) will have a material impact on near-term power sourcing — our corporate discussions suggest larger utilities and developers have received safe harbor for utility-scale solar and onshore wind projects coming online over the next four years by meeting the latest guidance from the US Internal Revenue Service to qualify for federal incentives before they sunset. At our September 25 Global Sustainability Forum, there was healthy debate, however, as to whether we will see a deceleration in renewables capacity additions post 2028; our Utilities and Clean Technology teams assume modest deceleration in their base case. **Beyond incentives,**

permitting remains key from a policy perspective and the extent/success of pushes by federal and local policymakers/regulators to speed up timing for permitting decisions.

Exhibit 10: We continue to see a Green Reliability Premium for clean energy solutions that meet baseload power demands of data centers — on average these have a $40/MWh higher supply cost in the US, rising to $48/MWh after Inflation Reduction Act incentives sunset
US levelized cost of energy of various fuel & technology combinations to power new data centers inclusive of assumed transmission/distribution (except intermittent solar/wind); potential implications with proposed IRA revisions (assumes no changes to nuclear incentives)



Source: Goldman Sachs Global Investment Research

Exhibit 11: The Green Reliability Premium in the US, conservatively applied to global datacenter power demand growth in 2030 vs. 2023, is modest in comparison to hyperscalers' EBITDA and corporate returns

US Green Reliability Premium applied to global data center power demand growth in 2030 vs. 2023 relative to 2027E and 2030E EBITDA and 2026E cash return on cash invested; base case vs. scenario of 10% increase in capital costs across all sources of generation

	US incentives pre-IRA sunset	US incentives post-IRA sunset
Baseline levelized cost of energy, US, $/MWh	$67	$67
Green Reliable levelized cost of energy average, US, $/MWh	$107	$115
Average US Green Reliability Premium, $/MWh	**$40**	**$48**
Global data center power demand (TWh)		
2023	411	411
2030E	1,131	1,131
Increase, 2030E vs. 2023	**720**	**720**
Required 2030E industry outlay if applying US Green Reliability Premium, $ bn	**$29**	**$34**
Hyperscaler total company EBITDA, 2027E, $ bn	$972	$972
% of hyperscaler 2027E EBITDA	3.0%	3.5%
Hyperscaler 2030E EBITDA (at 10% CAGR vs. 2027E)	$1,294	$1,294
% of hyperscaler 2030E EBITDA	2.3%	2.7%
Hyperscaler average CROCI, 2027E	30.4%	30.4%
CROCI impact from industry 2030E Green Reliability Premium	-0.8%	-0.9%
Adj. CROCI if hyperscalers cover industry Green Reliability Premium	29.6%	29.5%

Baseline source is combined cycle natural gas; Green Reliable sources are large nuclear, SMR nuclear, solar + storage + gas peaker, solar + offsite wind + storage.

Source: Goldman Sachs Global Investment Research

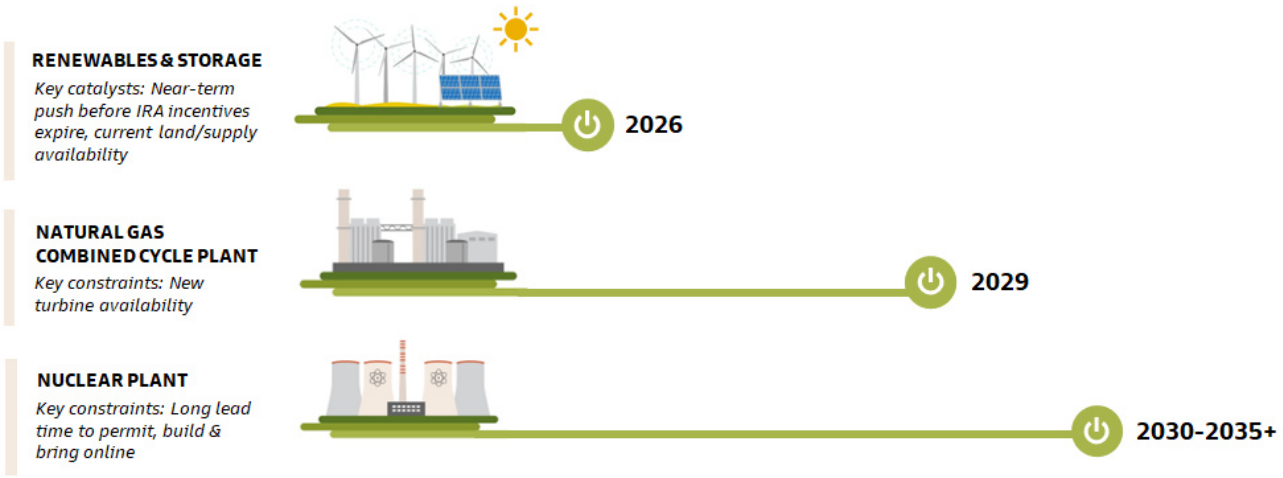
While we see affordability as less of a concern for sourcing data center power demand, we continue to believe Affordability — and the implications of data center demand on Affordability and Reliability — will continue to be a broader debate.

Parts: Availability and lead times key to power sourcing

We believe power sourcing will be governed more by availability and risk management than by supply cost. This leads to a relatively greater weighting towards utility-scale solar/battery storage/natural gas peaking plants in the near term, natural gas combined cycle in the medium term and nuclear in the long term. Our base case continues to assume that this decade, 40% of the data center power increase will be met with renewables, and we assume a modest nuclear capacity increase by the end of the decade targeted for data centers. The bulk of the remaining 60% we expect will be driven by natural gas generation — a combination of combined cycle and peaking plants. Contracting for power purchase agreements (PPAs) by technology companies was robust in 2024, rising to 33 GW from around 18 GW in 2023. Overall, we see global carbon dioxide emissions from data centers (excluding carbon capture and non-PPA offsets) rising by 215-220 million tons in 2030 vs. 2023 levels, equivalent to 0.6% of global energy emissions. We continue to see potential for a significant reduction of data center emissions intensity and potentially in absolute emissions in the 2030s driven by:

- Increased contribution to power sourcing from nuclear generation.
- Declining AI server energy intensity as the focus within AI shifts more towards inference (less energy intensive) vs. training (more energy intensive), though the energy demands of inference are in some debate depending on the pervasiveness and innovations in reasoning and automation.

Exhibit 12: How long would it take to build & bring new power generation online?
A look across power sources



Source: Goldman Sachs Global Investment Research

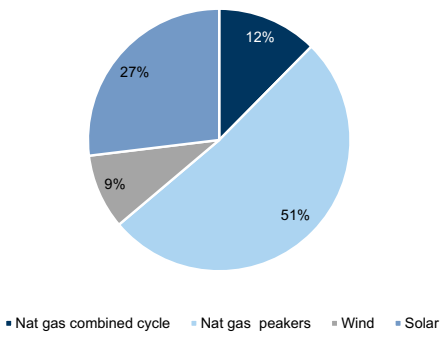
Exhibit 13: We see advantages and challenges across the various technologies which can provide capacity for data center-driven power demand

	Capacity Factor	Emissions Intensity	Land Footprint Intensity	Advantages / Challenges
Solar		—		**Advantages:** carbon footprint **Challenges:** land requirements, intermittent power
Onshore Wind		—		**Advantages:** carbon footprint **Challenges:** land requirements, intermittent power
Nuclear Large Scale		—		**Advantages:** small land footprint, reliable, carbon footprint **Challenges:** waste, labor, enriched uranium supply, lead time
Nuclear SMR		—		**Advantages:** small land footprint, reliable, carbon footprint **Challenges:** waste, labor, enriched uranium supply, lead time
Battery Storage		—		**Advantages:** enables greater clean energy reliability **Challenges:** capacity limits
Natural Gas CCGT				**Advantages:** reliable, small land footprint **Challenges:** turbine availability, gas price volatility, emissions
Natural Gas Peaker				**Advantages:** reliable, small land footprint **Challenges:** gas price volatility, less carbon efficient vs. CCGT
Grid (natural gas)				**Advantages:** reliable, land footprint **Challenges:** carbon footprint, interconnection wait times

Source: Goldman Sachs Global Investment Research

Exhibit 14: Of the 82 GW of incremental capacity adds in the US to serve data center driven load through 2030, we expect 51% to come from natural gas peaking plants and 27% to come from solar

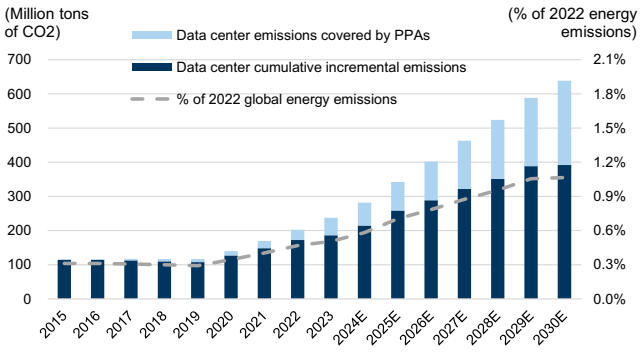
Mix of expected generation capacity additions through 2030 to support US data centers, %



Source: Goldman Sachs Global Investment Research

Exhibit 15: We see data center emissions doubling in 2030 vs. 2023 levels, net of impact of power purchase agreements (PPAs) from technology companies

Carbon dioxide emissions in millions of tons (LHS); percent of 2022 energy emissions (RHS)



Source: IEA, Goldman Sachs Global Investment Research

People: Transmission & Distribution skilled labor key area of risk

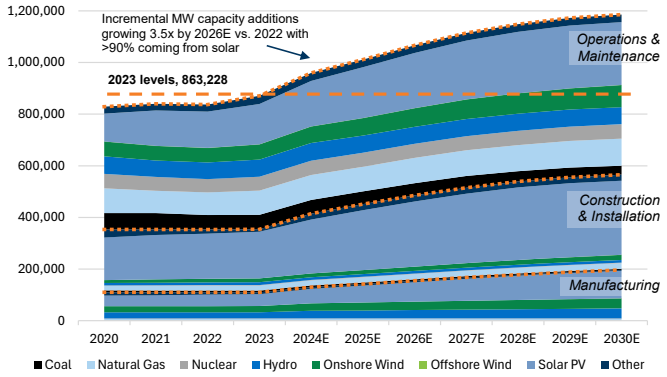
Sharp rise in demand with skilled labor needs for grid connectivity a greater area of potential constraint than generation capacity buildout. Generational growth in power demand is likely to have broad implications for a labor network already facing strain from aging and a limited pipeline of skilled labor. To meet our US/Europe Utilities teams' power demand growth estimates for 2023-2030, we estimate an additional ~510K US jobs (power & grids) and ~250K EU jobs (power) will be required. This new labor demand comes within a backdrop of an already tight labor market, adding potential constraints to the rate at which power demand can grow.

In our view, transmission & distribution (T&D) poses a greater risk of exacerbating project delays and is an area where labor disruption elsewhere via AI / layoffs is unlikely to be a sufficient source of supply given the high skills requirements for T&D. This will likely accelerate the deployment of grid optimization/automation/labor efficiency solutions, and potentially benefit incumbent contractors/utilities with a competitive advantage in labor access.

- **We view labor challenges associated with US renewables construction and Europe operations & maintenance** (52% of the total job growth needed) **as lower risk** due to the relatively low level of training and skilling required for execution and greater automation potential.
- **We see the greatest potential labor constraint from the skilled labor needed for electricity transmission & interconnections** (207K new US jobs, implying 22% growth), roles that require significantly greater skilling (3-4 years of training) amid an aging workforce. In the US, there are ~45K active apprentices in the energy sector (e.g., electricians, lineworkers, powergrid technicians) according to the US Department of Labor. To achieve our estimate for transmission labor and offset retirements, we believe the run rate of active energy sector apprentices may need to increase by about 20K-30K.

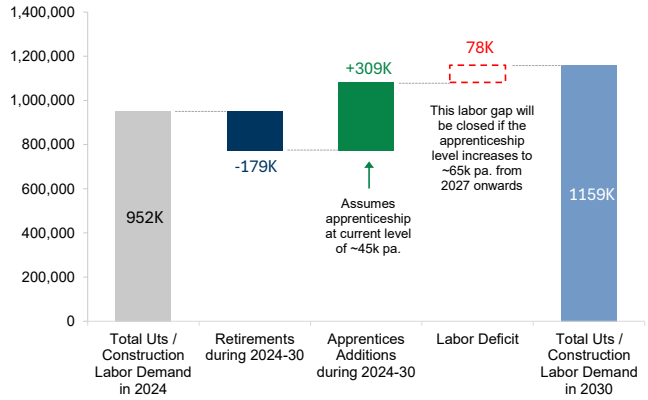
While we believe our power demand growth outlook (driven not just by AI/data centers) is achievable, the need for transmission and distribution skilled labor represents a key risk.

Exhibit 16: In the US, ~300K additional jobs, across manufacturing, construction, and operations, will be needed to meet power demand by 2030 by our estimates; we also see an additional ~207K jobs needed in our base case for transmission and distribution
Jobs required to meet US power supply by 2030E



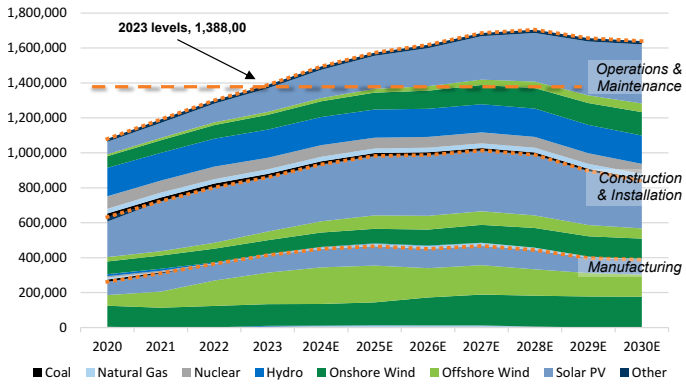
Source: US Department of Energy, Goldman Sachs Global Investment Research

Exhibit 17: Assuming all energy-related apprenticeships are deployed to T&D, there is still a 78K labor gap in our base case to meet our estimated T&D jobs needed by 2030
Total US labor demand for utility and construction transmission & distribution, 2024-2030E



Source: US Department of Labor, Goldman Sachs Global Investment Research

Exhibit 18: In Europe, we estimate an additional 250K jobs will be needed by 2030 to meet new power demand growth
Jobs required to meet Europe power supply 2020-2030E



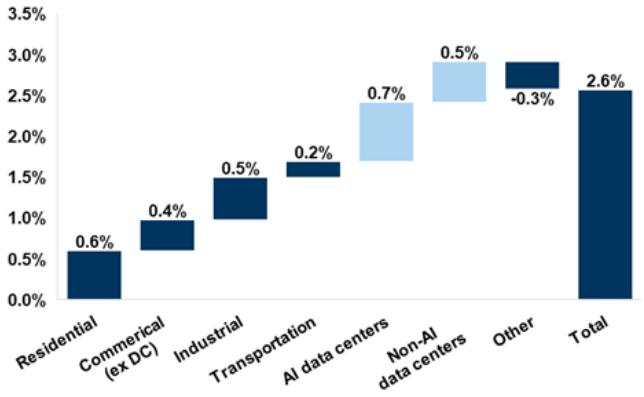
Source: SNL Energy, EIA, IEA, IAEA, Ram et al. (2022), Goldman Sachs Global Investment Research

US Power Demand Growth Implications

The upward revisions to our data center power demand estimates, driven by our TMT team's increased server shipment outlook and data capacity buildout, raises our overall US power demand estimate to 2.6% CAGR through 2030. Our new data center power demand estimates now make up for ~11% of total US power demand by 2030, up from our previous estimate of 10% of total demand. Data centers made up roughly 4% of overall power demand in 2023, per the latest actuals from the DOE. Within data center power demand, we now expect roughly 39% to come from AI in 2030 in our estimates, up from 32% before, and non-AI data centers to represent the remaining 61%. Overall data centers now contribute about ~120 bps of growth to our 2.6% US power demand CAGR through 2030, with about 70 bps coming from AI data centers. As such, if we adjusted AI growth out of our model, we would still expect to see US power demand CAGR of about ~2% through 2030, well above growth in recent years.

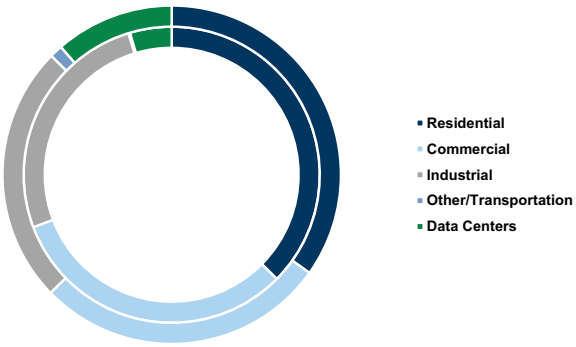
On the supply side, we raise our capacity estimates needed to support the increased load growth from data centers. We now assume ~82 GWs of overall capacity is needed to meet data center demand, from 72 GWs previously. This assumes ~60% of data center demand requires new capacity versus utilizing existing supply. We maintain our view that new capacity will be split 60/40 between natural gas and renewables, with a 40% CCGT/20% peaker composition for gas and 15%-30% for solar and wind for renewables.

Exhibit 19: Data centers make up 1.2 pp of our 2.6% CAGR estimate through 2030
Weighted average growth rates



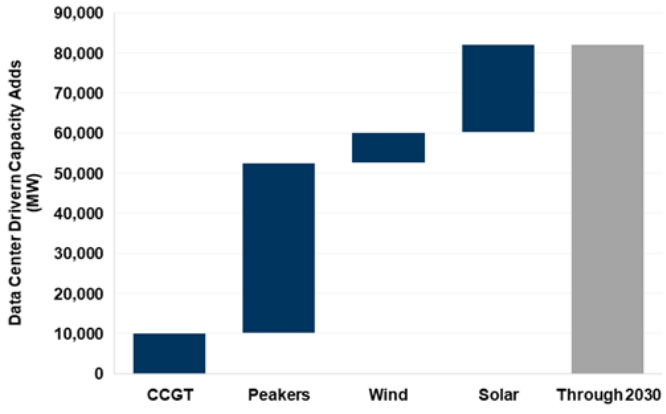
Source: EIA, Goldman Sachs Global Investment Research

Exhibit 20: Data centers make up 11% of overall power demand in 2030 vs ~4% in 2023
Demand by customer class (2023 vs. 2030)



Source: Goldman Sachs Global Investment Research, EIA

Exhibit 21: Our new estimates imply roughly 82 GWs of new generation capacity coming online through 2030, up from roughly 72 GWs
Capacity additions from data center demand

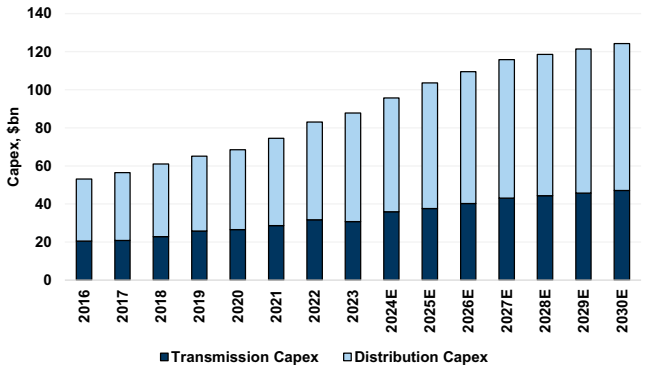


Source: Goldman Sachs Global Investment Research

Significant grid investment required to sustain datacenter growth

We continue to believe that the electric grid will require significant investment, not solely related to datacenters but a broader rise in power demand, where we now see increased growth of 2.6% CAGR in the US through 2030. We update our grid investment expectations through 2030, increasing our estimates mostly on higher distribution capex, based on higher updated forecasts from EEI in 2025. We now expect roughly $790 bn of grid spend through 2030, up from $780 bn in our last update, with the bulk of the spending still focused on distribution, but with faster expected growth in transmission capex. Notably, out of the aggregate capital investment plans disclosed by companies under our coverage in their five-year plans, our expectation is that roughly 67% should be allocated to transmission and distribution/ grid enhancement.

Exhibit 22: Our forecasts imply $790 bn of grid capex through 2030, up from $780 bn in our last update
Grid capex, $ bn



Source: Company data, Goldman Sachs Global Investment Research, EEI

Disclosure Appendix

Reg AC

We, Brian Singer, CFA, Carly Davenport, James Schneider, Ph.D., Evan Tylenda, CFA, Alberto Gandolfi, Brendan Corbett, Varsha Venugopal, Beatriz Abreu, CFA, Jaya Patel, Michael Smith, Xavier Zhang, Grace Chen and Shubham Jain, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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Growth is based on a stock's forward-looking sales growth, EBITDA growth and EPS growth (for financial stocks, only EPS and sales growth), with a higher percentile indicating a higher growth company. **Financial Returns** is based on a stock's forward-looking ROE, ROCE and CROCI (for financial stocks, only ROE), with a higher percentile indicating a company with higher financial returns. **Multiple** is based on a stock's forward-looking P/E, P/B, price/dividend (P/D), EV/EBITDA, EV/FCF and EV/Debt Adjusted Cash Flow (DACF) (for financial stocks, only P/E, P/B and P/D), with a higher percentile indicating a stock trading at a higher multiple. The **Integrated** percentile is calculated as the average of the Growth percentile, Financial Returns percentile and (100% – Multiple percentile).

Financial Returns and Multiple use the Goldman Sachs analyst forecasts at the fiscal year-end at least three quarters in the future. Growth uses inputs for the fiscal year at least seven quarters in the future compared with the year at least three quarters in the future (on a per-share basis for all metrics).

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