

GS SUSTAIN: AI/DATA CENTERS

Power demand, cyclical progression and Sustainability implications

Continued upward revisions to hyperscaler capex, server/model productivity gains and US community pushback to data center development have increased inbound questions on how long the AI innovation cycle can continue to fuel the Reliability investment theme and drive upside to stocks of the AI/data center power supply chain. At the same time, Sustainability-focused investors continue to debate how to position for AI in their portfolio, governance and engagement strategies. In this report, we detail our latest views on three topics:

1. AI/data center power demand and the 7 Ps driving growth/constraints — **P**ervasiveness, **P**roductivity, **P**rice, **P**olicy (including accelerated US community pushback to data center development), **P**arts, **P**eople and **P**hysical environment.
2. AI innovation cycle progression based on learnings from the shale innovation cycle.
3. Sustainability implications of AI — potential costs vs. potential benefits.

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Key takeaways

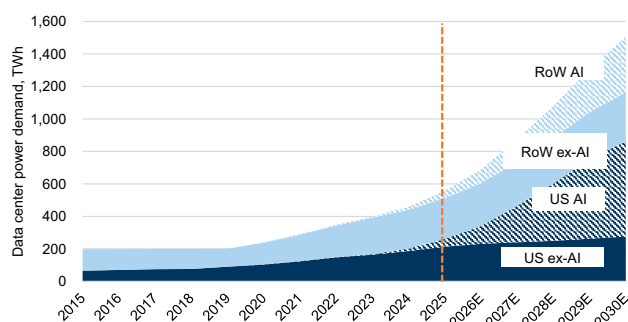
- 1. AI/data center power demand growth/constraints:** We recently made upward revisions to our global AI/data center power demand and now assume 170% global data center power demand growth in 2030 vs. 2025 levels (117% previously). The cumulative power growth by 2030 vs. 2023 levels (1,100 TWh) from data centers would exceed the 2023 power consumption of Japan (#5 power consuming country in the world). We continue to see an all-of-the-above approach to power sourcing with a majority coming from natural gas and substantial contributions from renewables. PPA contracts signed by technologies for renewables + nuclear in 2025 grew by 17% yoy. Community pushback in the US (reliability/affordability of water/power, noise, localized warming) remains a key risk to timing of data center development, even as there are solutions to mitigate the key areas of concern.
- 2. AI innovation cycle lessons from the shale innovation cycle:** We appear closer to the inflection from AI's Appraisal/Hopes & Dreams Phase to the Execution/Efficiency Phase based on the metrics that drove the inflection for the shale innovation cycle. However, industry commentary reflects continued pent-up demand for compute/tokens, and we continue to see innovator financial flexibility via strong balance sheets even as corporate-level returns for hyperscalers are implied by our analysts' forecasts to decline.
- 3. Sustainability AI outlook:** We believe Sustainability-focused investors should view AI implications as the net of social value from potential AI benefits advancing Sustainable Development Goals less social costs from emissions/footprint/labor/risks.

Data Center Power demand: The 7 Ps driving growth/constraints

As hyperscaler capex and data center buildout rises, so too has our data center power demand estimates. On the back of greater data center capacity, recent increases from our TMT team to AI server shipments forecasts and our US power team's regional outlook on data center power demand, we recently raised our global forecasts for global data center power demand through 2030. We see 170% global data center power demand growth in 2030 vs. 2025 levels (117% previously), which also incorporates estimated historical data center power demand following recent reports by the DOE and IEA.

Exhibit 1: We see 170% global data center power demand growth in 2030 vs. 2025 levels, more than 60% of which comes from the US

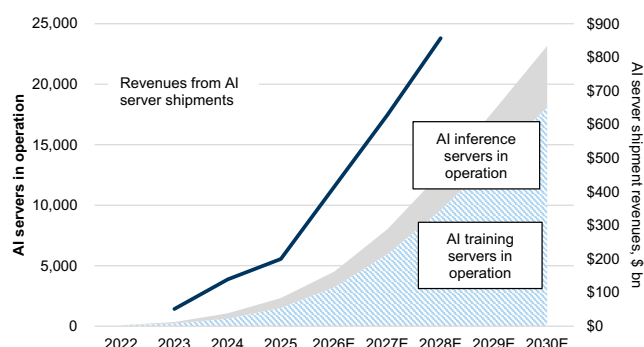
Data center (AI + non-AI) power demand in US and rest of world, TWh



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

Exhibit 2: 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)



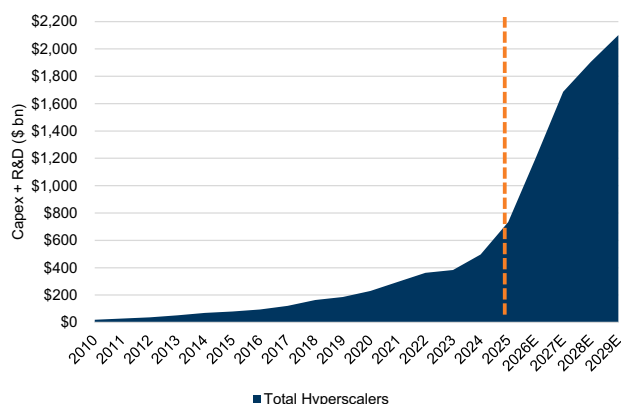
Source: Goldman Sachs Global Investment Research

Pervasiveness of AI: Hyperscaler capex expectations continue to be revised higher

Greater industry AI capex has contributed to increased server shipments and data center capacity. Ultimate returns-enhancing AI outcomes will be critical to longevity. Several hyperscalers have recently raised AI-related capex forecasts, fueling ongoing debates around the scale and sustainability of this spend. **Alphabet** raised its 2026 capex range by \$15 bn and continues to expect substantial increases in capex yoy in 2027. **Amazon** hiked its 2026 capex target by \$20 bn and **Meta** raised the lower end of its previous 2026 forecast range from \$125-\$130 bn. Looking forward, Capex in 2027 is still expected to “increase significantly” according to one hyperscaler, and additional commentary suggested a “supply-constrained” environment. However, there remains healthy debates on how widespread and returns-enhancing AI will be for innovators.

Exhibit 3: Hyperscaler capex + R&D now expected by our analysts to exceed \$1 trillion in 2026E, with continued growth in future years

Total company annual capex + R&D for hyperscalers, \$ bn



Hyperscalers include Alphabet, Microsoft, Meta, Amazon, Oracle, Baidu, Tencent, Alibaba

Source: Company data, Goldman Sachs Global Investment Research

Productivity of chips/servers/models: Demand elasticity is key
We continue to assume energy intensity reductions for AI (compute per unit of power) at a faster pace than for non-AI. However, pent-up demand for tokens/compute is likely to continue until there is more corporate/government confidence that:

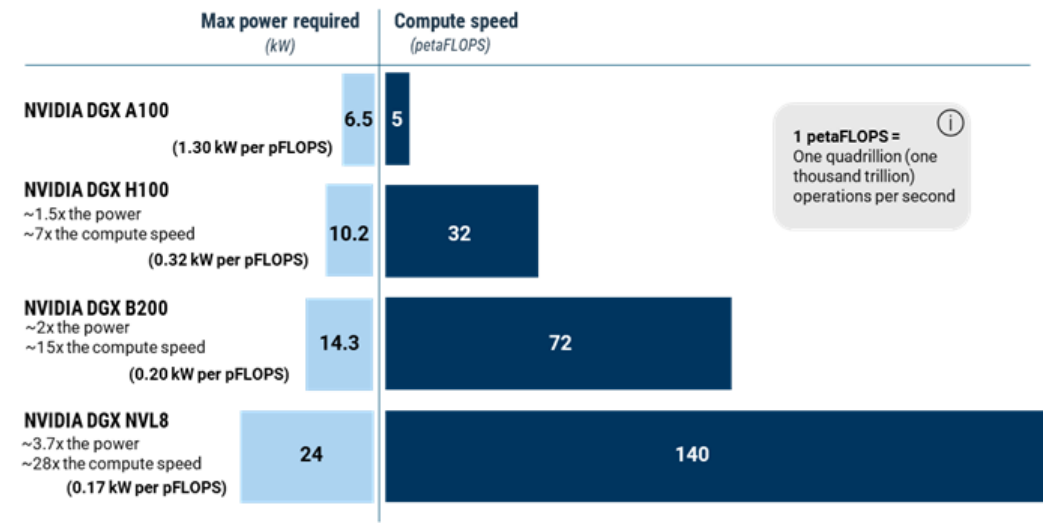
- Reducing budgets will not sacrifice competitive positioning; or
- Their demand for tokens/compute has been sufficiently defined.

At that point, AI will shift from the Appraisal/Hopes & Dreams Phase to the Execution/Efficiency phase, characterized by downward revisions to budgets in response to productivity gains.

We believe based on recent industry commentary and our Power & Resources Reliability trip in 2Q26 that **we are seeing signs of a push towards capital efficiency among consumers as it relates to their spending per token** — putting structures in place to monitor and manage where tokens/compute is being consumed and by whom within organizations. This is a sign towards consumer efficiencies and optimization, though it is unclear that this will in aggregate reduce appetite for organizations to increase token/compute consumption in response to producer productivity gains.

Exhibit 4: AI innovations increase max power consumption per server but increase compute speed per server by an even greater level, representing a meaningful reduction in power intensity per unit of compute

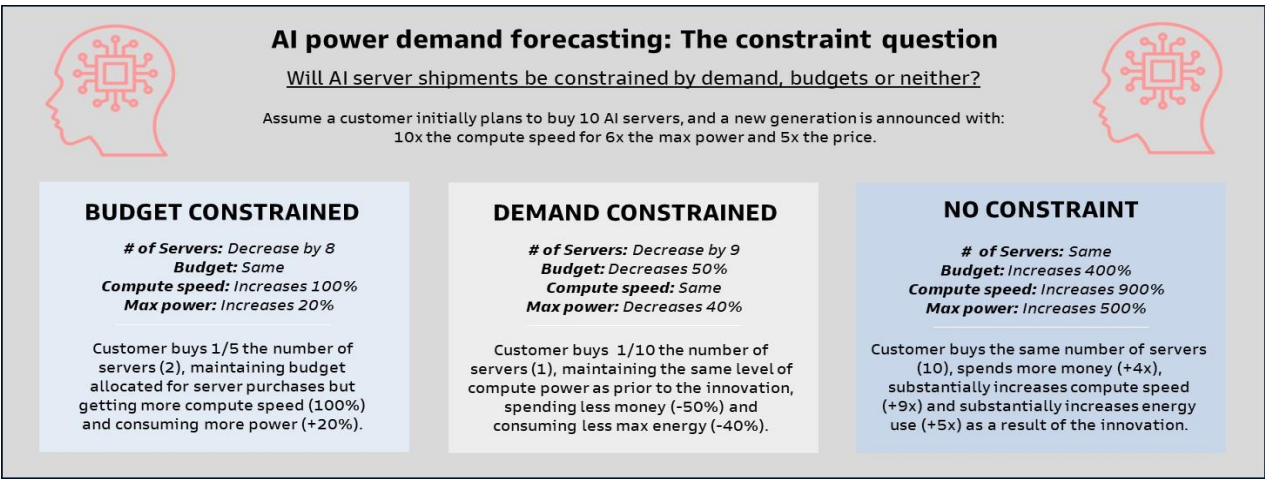
Recent evolution of NVIDIA server system specifications is indicative of increasing max power per server but with lower power relative to computing speed (for training)



Source: NVIDIA, Goldman Sachs Global Investment Research

Exhibit 5: We are not yet in a demand constrained environment where token/compute producer efficiencies drive lower producer/consumer budgets, though consumers are moving to optimize token/compute usage

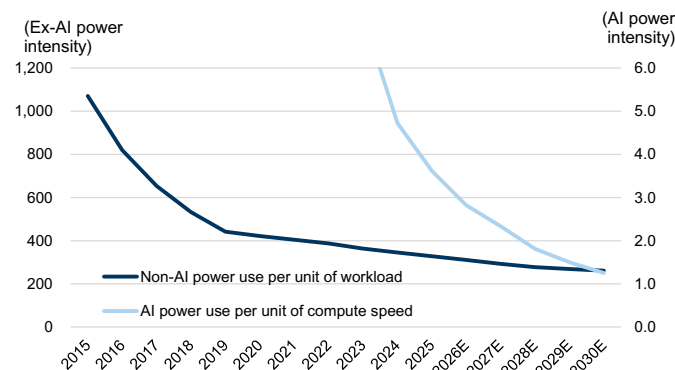
Indicative scenario analysis of how demand vs. budget constraints could impact AI compute speed and power use



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

Source: Goldman Sachs Global Investment Research

Exhibit 6: Our forecasts imply a swifter pace of energy efficiency per unit of demand for AI relative to non-AI
Power demand per unit of workload for non-AI and per unit of compute speed for AI



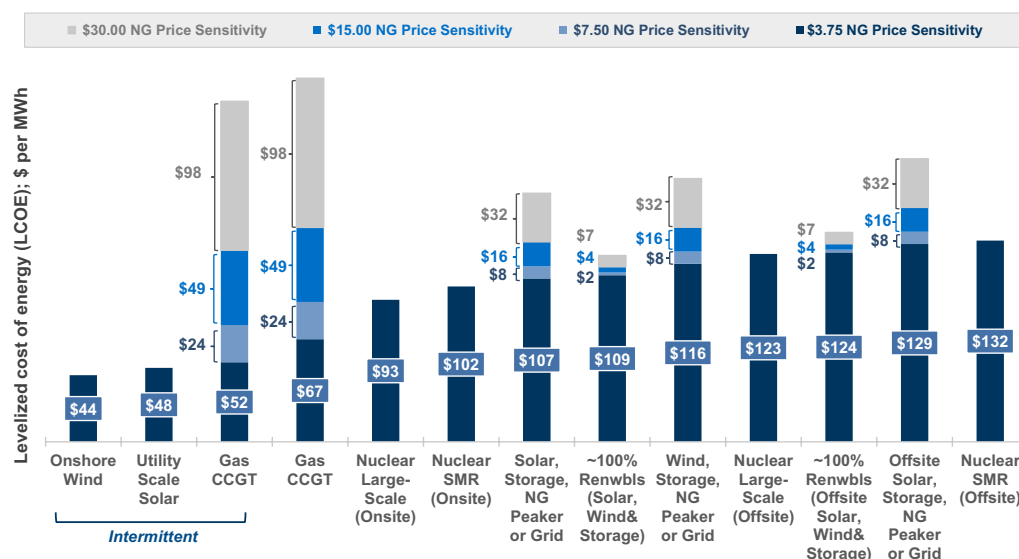
Source: Masanet et al. (2020), IEA, Cisco, Goldman Sachs Global Investment Research

Price of power: Remains less a constraint to hyperscalers

Actual/risk of higher power prices remains a key community concern (in addition to reliability of power/water), though we believe hyperscalers continue to have financial flexibility via strong balance sheets that will drive both willingness to accept higher power costs and willingness to sign take-or-pay contracts. While we see a Green Reliability Premium in the US for round-the-clock low-carbon forms of power — solar/wind + storage + natural gas peaker, nuclear, etc relative to natural gas combined cycle — we do not believe the higher power supply cost will limit hyperscaler willingness to take an all-of-the-above approach to power sourcing. While the Green Reliability Premium remains in the US, there remains a substantial benefit for natural gas combined cycle generation due to low natural gas prices which are not seen in Europe, Japan, Korea and areas which import LNG. However, we note that recent commentary from power producers suggests a scenario of higher capital costs for natural gas combined cycle vs. our base case which, all else equal, would narrow the Green Reliability premium in the US and globally.

Exhibit 7: Natural gas price plays a meaningful role in the extent or existence of a Green Reliability Premium to supply power

Levelized cost of energy of various fuel & technology combinations of new power generation inclusive of assumed transmission/distribution (except intermittent solar/wind); potential sensitivities based on various natural gas prices



Source: Goldman Sachs Global Investment Research

Exhibit 8: The Green Reliability Premium in the US, conservatively applied to all 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 2028E and 2030E EBITDA and 2028E cash return on cash invested

	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	399	399
2030E	1,506	1,506
Increase, 2030E vs. 2023	1,107	1,107
Required 2030E industry outlay if applying US Green Reliability Premium, \$ bn	\$45	\$53
Hyperscaler total company EBITDA, 2028E, \$ bn	\$1,549	\$1,549
% of hyperscaler 2028E EBITDA	2.9%	3.4%
Hyperscaler 2030E EBITDA (at 10% CAGR vs. 2028E)	\$1,874	\$1,874
% of hyperscaler 2030E EBITDA	2.4%	2.8%
Hyperscaler average CROCI, 2028E	27.2%	27.2%
CROCI impact from industry 2030E Green Reliability Premium	-0.7%	-0.8%
Adj. CROCI if hyperscalers cover industry Green Reliability Premium	26.5%	26.4%

Baseline source is combined cycle natural gas; Green Reliable sources are large nuclear, SMR nuclear, solar + storage + gas peaker, solar + offsite wind + storage. Hyperscalers include Google, Microsoft, Meta, Amazon, Oracle, Baidu, Tencent, Alibaba.

Source: Goldman Sachs Global Investment Research

Policy: US community pushback, solutions and path forward

Permitting/community pushbacks and potential solutions remain in focus.

Permitting and executability continues to be a source of industry frustration as well as key area of investor focus. There appears to be bipartisan support in the US for speeding up processes, while at the same time we have also seen increased bipartisan support for delaying data center development until there is sufficient confidence there will not be an adverse community impact. Among key states for data center development:

- The governor of TX (13% of expected new US data center capacity through 2030) published an executive order on August 3 requiring audits and data disclosure around some of the key areas of pushback we describe below in order to receive approvals for grid connectivity.
- We have seen recent bipartisan calls for moratorium in Virginia (17% of expected new US data center capacity through 2030) to ensure there will be sufficient power supply/grid connectivity.

Exhibit 9: While we see solutions for the key areas of pushback to data center development, community concern may remain elevated

Perceived Risks	Rationale	Regional Variability	Mitigating Solutions
Power Outages 	Greater power demand can = greater grid stress	Fairly ubiquitous concern	Data center agrees to power interruptions if necessary; behind-the-meter capacity *
Higher Power Prices 	Greater utility capex or tightening power supply/demand can = higher rates	Fairly ubiquitous concern	Take-or-pay tariff structures; capacity market reform; behind the meter capacity *
Drain on Water Supply 	Cooling modern data centers can be water intensive	Less of a concern in areas of water abundance	Closed-loop, waterless or less water-intensive cooling systems
Noise Pollution 	HVAC & onsite power gen increase local ambient noise	Most acute in landscapes with proximity between DCs and residences.	Zoning adjustments, acoustic barriers, sound-dampening fans
Localized Warming 	Thermal output of datacenters can ↑ local heat stress	Less of a concern in cold climates or where heat recycling infrastructure exists	Waste heat capture for district heating or other recycling solutions, where possible

* ongoing debate on the long-term efficacy of behind-the-meter solutions

Source: Goldman Sachs Global Investment Research

Increased attention to risks of delays driven by US community pushback to data center development is driving greater connectivity between corporates, investors and communities on potential solutions even as it creates risk to the pace of data center

development.

The key areas of pushback from communities/broader consumers and potential solutions are:

- **Risk of power reliability issues.** Our discussions with hyperscalers/utilities/policymakers suggest increased license to operate by data centers requires a willingness to be interrupted in the event of outage risk, likely driving more backup power and/or backup data center capacity to accommodate. While grid power is still a preferred solution for hyperscalers vs. behind-the-meter (BTM), time-to-market priorities is leading to greater deployment of BTM solutions, more of which are likely to remain onsite to provide backup power in our view when grid connectivity ultimately occurs as a solution to community power reliability concerns.
- **Risk of rising power prices.** Our discussions with hyperscalers/utilities/policymakers suggest greater deployment of take-or-pay contracts as a solution to mitigate the risk of price leakage. This is also becoming license to operate, in our view. Providing the right mechanisms to execute on this in unregulated markets like PJM in the Mid-Atlantic and ERCOT in Texas continue to be debated. Ultimately there are multiple factors — including replacing aging infrastructure and increasing resiliency to physical risk — that drive utility investment beyond rising demand. Our US Utilities team expects average consumer bills to rise by 3%-6% annually through 2029, while our EMEA Utilities team expects Europe average consumer bills to rise by 2%-4% annually through 2030.
- **Risk of depletion of water supply.** Our discussions with hyperscalers/corporates suggest increased deployment of water-minimizing closed-loop liquid cooling systems in the “white space” to cool the inside of the data center — 43% of total data center capacity globally. In areas that have high ambient heat/humidity, the options to reject heat to the outside (“gray space” cooling) are relatively more limited to chillers that consume more power vs. evaporative systems. This opens up a water vs. power tradeoff that data center developers face, which we discussed in both our July 13 report, How heat, humidity and water use minimization could drive data center cooling, power demand and stocks, as well as later in this report. We believe in much of the US, there will be priority for water usage minimization which in areas with high heat/humidity could drive otherwise greater power consumption. So solutions to water minimization may put more pressure on the need to deploy solutions discussed above to mitigate power reliability/affordability concerns.
- **Risk of community opposition from noise pollution.** Recent media reports suggest noise is becoming an increasingly important license-to-operate issue, particularly when larger AI-oriented data centers are built closer to residential areas. Unlike many industrial sources that see activity decline overnight, data centers operate continuously, generating low-frequency noise and vibration from cooling equipment, ventilation systems and backup generators. Existing noise regulations are often based on conventional decibel measurements that may not fully capture low-frequency sound, creating a gap between technical compliance and community acceptance. As a result, developers face a growing risk of permitting delays, legal

challenges and additional mitigation costs, particularly in densely populated areas. We expect greater adoption of acoustic shielding, enhanced site buffers and liquid cooling technologies, which can materially reduce fan-related noise while also improving thermal management efficiency.

- **Localized warming impact from rejected heat.** Recent pushback to Utah's Stratos data center project — and subsequent project scope changes — highlights risks that large-scale data center developments could intensify local heat stress alongside water depletion. In this context, redirecting heat into productive use reduces thermal discharge to the environment and reframes data centers from heat sources into energy suppliers potentially — increasingly important as social license becomes a gating factor for new capacity. While waste heat capture at data centers is in earlier stages, we note it is being done in areas such as Finland and France and can serve as a solution where the economics warrant.

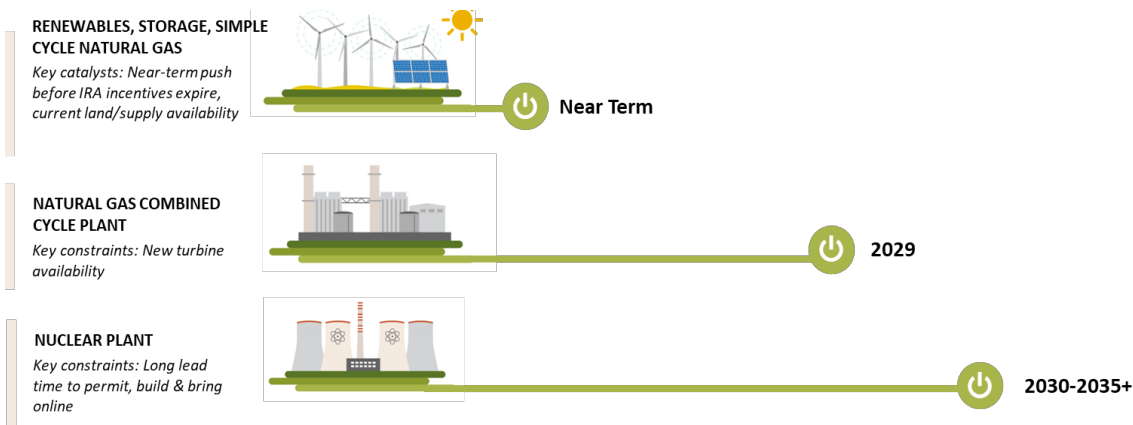
These solutions may not fully allay community concerns, where perception of the societal and/or economic impacts of AI, transparency of the individual data center development process and broader NIMBY pushback could supersede innovation/solutions.

Parts availability

Constraints in timing/availability of power generation equipment continues to drive how data center power will be sourced as part of an overall 'yes, and,' all-of-the-above strategy — renewables/battery storage/simple cycle natural gas in the shorter term, natural gas combined cycle in the medium term, nuclear in the longer term. Parts constraints are driving greater deployment of behind-the-meter solutions — which largely though not entirely source power from natural gas — to push forward startup times until grid connectivity arrives. While there remains a preference for the grid, the increased license to operate (in the US at a minimum) to accept interruptibility in the event of grid outage risk may keep BTM solutions deployed as backup once the grid comes online. While parts availability is not solely driven by natural gas combined cycle turbines, we note that GE Vernova highlighted on its July 22 2Q26 earnings call that by the end of 2026 it expects to have more than 50% of its 2031 capacity contracted. Our US Utilities team sees US power demand growing at a 3.5% CAGR through 2030, of which 0.8 pp is sourced via behind-the-meter solutions.

Exhibit 10: How long would it take to build & bring new power generation online?

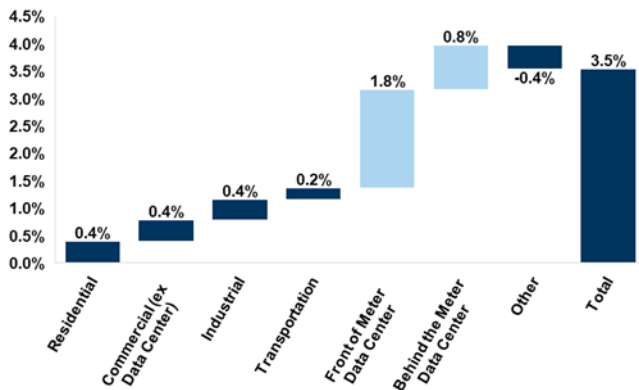
A look across power sources



Source: Goldman Sachs Global Investment Research

Exhibit 11: Our Utilities team’s total US power demand CAGR is now 3.5% through 2030, with the bulk of upward revisions YTD sourced via behind-the-meter solutions

Overall US power demand CAGR by driver

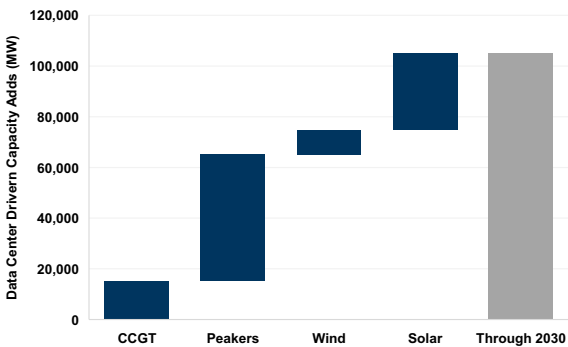


Numbers do not sum to total due to rounding.

Source: Goldman Sachs Global Investment Research

Exhibit 12: We see about 139 GW of incremental capacity adds to serve data center driven load through 2030

Capacity additions from data center demand



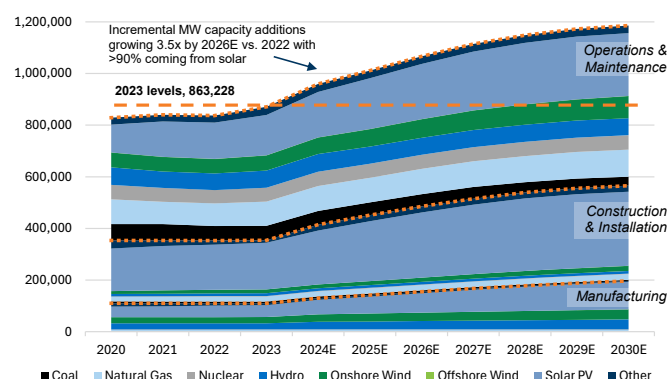
Source: Goldman Sachs Global Investment Research

People availability

We continue to see >500K new jobs to meet overall US power demand growth (>700K when including Europe as well). More than 200K of the US needs is to meet transmission and distribution connectivity. We continue to see risks that skilled labor availability constraints — particularly electricians — represents a key risk to execution. This is also, in our view, helping to drive greater consideration for behind-the-meter power solutions that require less electricity transmission. Time-to-market priorities and long lead times for grid connectivity are driving behind-the-meter solutions — largely natural gas — than our US Utilities team expects will drive ~30% of the data center growth through 2030.

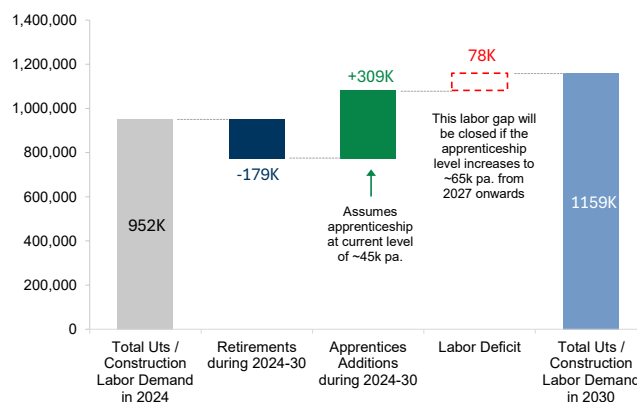
Exhibit 13: In the US, ~300K additional jobs, across manufacturing, construction, and operations, will be needed to meet power demand by 2030

Jobs required to meet US power supply by 2030E



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

Exhibit 14: 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

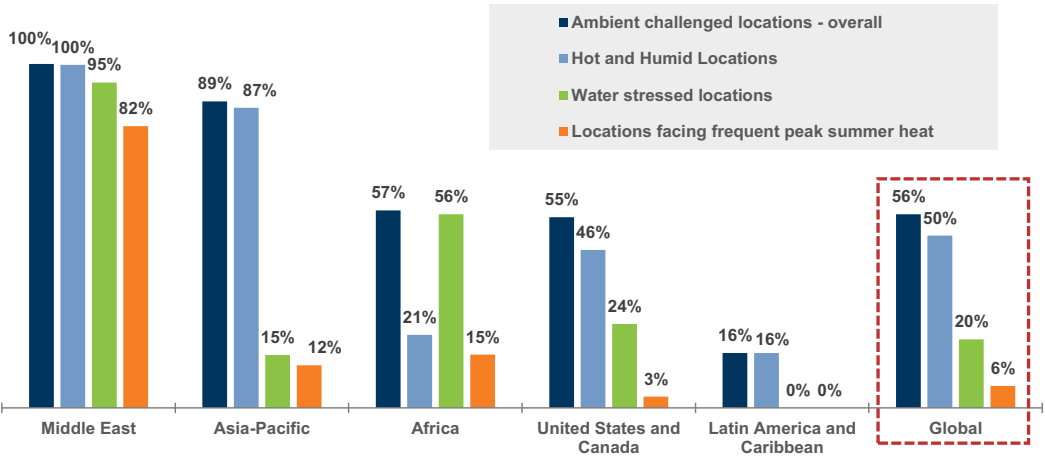
Physical environment: Heat/Humidity/Drought limit cooling impact, drive higher US power use to minimize water use

Ambient conditions — heat, humidity and drought — where data centers are being built are increasingly a driver of both stock performance and innovation. Higher heat, humidity and drought risks limit cooling technology selection optionality for data centers and requires greater power demand in affected regions where minimizing direct water demand is a priority.

- Our analysis suggests that 56%/55% of new global/US data centers are set to be built in areas with elevated physical risk to heat, humidity and/or drought.
- Based on our analysis of data center location and type, we expect that 43% of new data center capacity will deploy white space direct-to-chip or immersion cooling inside the data center. Separately, we expect 56% of new data center capacity will deploy gray space chillers, adiabatic systems or mechanical cooling back-up to transfer heat to the outside. We see this as at least a partial offset to efficiency gains, all else equal putting upward pressure on power usage effectiveness (PUE) and power demand.
- In the US, we believe water minimization will be the license-to-operate priority given resource constraints/costs, even if it comes with greater power demand. In China, the government has mandated minimum power usage effectiveness that is likely to result in otherwise greater water use. There continues to be innovation to try to minimize both water/power usage in areas with heat/humidity/drought (where as mentioned more than 50% of data centers are being built based on our analysis).
- In our base case estimates for AI/data center power demand, we moderate the annual pace of efficiency gains by expectations for a rise in power usage driven by ambient conditions equivalent to a 5 pp increase in power usage effectiveness globally and an 11 pp increase in PUE in the US.

Exhibit 15: 56% of global data center new capacity is located in areas facing ambient challenges including drought, humid heat stress and frequent summer extreme temperatures

% of data center new-build capacity (2026-2035) facing ambient challenges

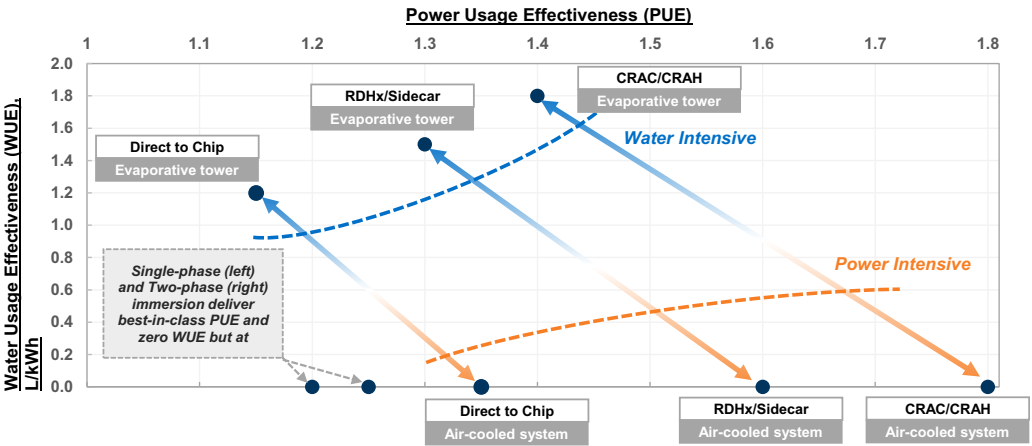


European data centers are less exposed to above physical risks; we measure physical risks under 2020 baseline scenario

Source: World Bank, 451 Research Datacenter KnowledgeBase, S&P Global Market Intelligence, Goldman Sachs Global Investment Research

Exhibit 16: Gray space cooling options to reject heat from the data center into the ambient environment come with a power versus water trade-off

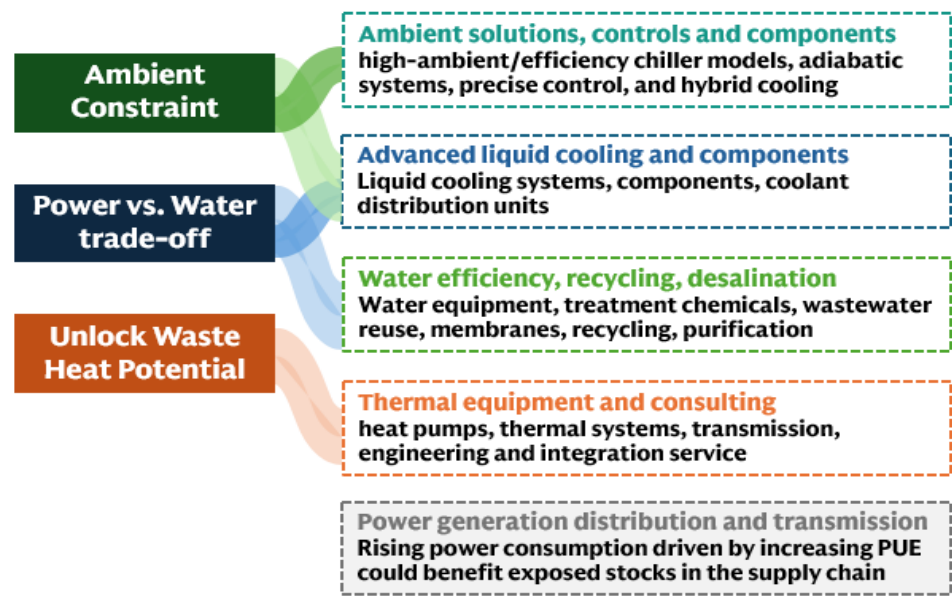
Power usage effectiveness (PUE) and water usage effectiveness (WUE) of different white/gray space cooling solution combinations



*Immersion cooling enables higher outlet temperatures (~50°C-60°C or above), allowing dry coolers to reject heat directly to ambient air without the need for chillers or evaporative towers

Source: University of Texas Energy Institute, Goldman Sachs Global Investment Research

Exhibit 17: We see five verticals that could see tailwinds from cooling pathway differentiation to mitigate ambient constraints, power vs. water trade-off, and power demand/waste heat debate



Source: Goldman Sachs Global Investment Research

AI Innovation Cycle learnings from the Shale Innovation Cycle: Updates to the 3 metrics that mattered

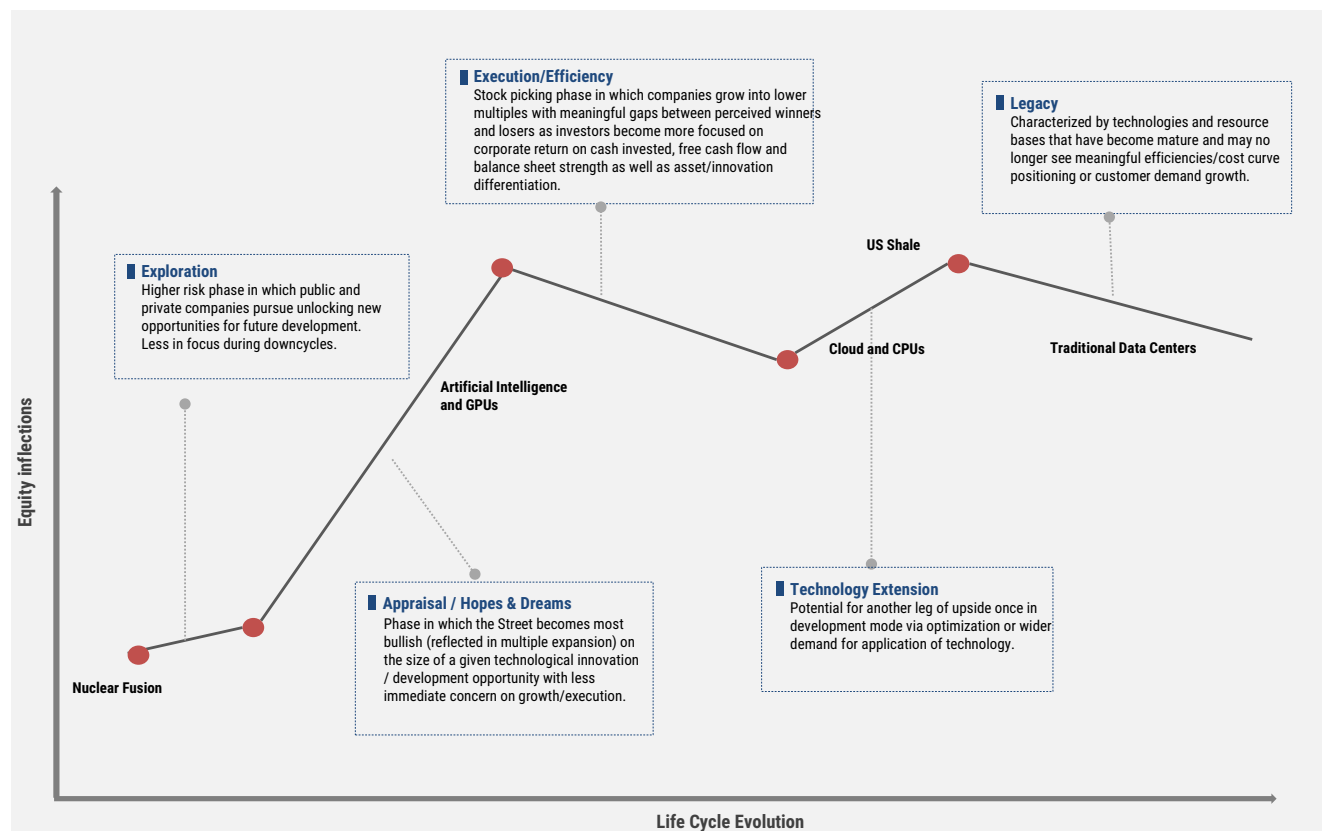
Shale innovation cycle implications for the AI innovation cycle. As we discussed in our January 2026 report, The AI Innovation Cycle: Investment lessons from the Shale Innovation Cycle, we see three key metrics to watch based on the shale innovation cycle that can drive an inflection from the **Appraisal / “Hopes & Dreams” phase** to the Execution / Efficiency phase (Exhibit 13):

- 1. When the product moves into oversupply from undersupply.** Compute/tokens supply-demand has been tight, with data-center vacancy rates still low and AI demand not yet demand defined. Thus far, AI server/chip/model productivity gains have been met with greater demand for tokens/compute rather than lower budgets. While we expect some degree of demand rationalization to occur as the utility and cost of various AI tools becomes more well defined, Jevons paradox is likely to spur on further demand as new efficiencies are achieved. The proliferation of Agentic AI is another demand driver that could further spike compute/token consumption. Our colleagues forecast Agentic AI deployment could increase token consumption 24x by 2030.
- 2. When innovators run out of financial flexibility.** Hyperscalers, as diversified incumbents, continue to increase capex + R&D, with the eight major hyperscalers now expected to invest \$1.2/\$1.7 tn in 2026E/2027E based on our analysts' latest estimates (Exhibit 12) after quarterly results reported the weeks of July 20 and July 27. This increases the reinvestment rate (the sum of capex + R&D / the sum of operating cash flow + R&D) above 99% in both 2026 and 2027 (Exhibit 14). While this reduces free cash flow financial flexibility, hyperscalers continue to have strong balance sheets on a weighted average basis (<0.5x 2026E net debt/2026E EBITDA). While our Credit Strategy and TMT teams also highlight hyperscaler financial flexibility that should lead to ability to tap credit markets in coming years, they also highlight market concentration limitations that could lead to diverse sources of financing at various costs of capital.
- 3. When corporate returns degrade, particularly if they become uncompetitive or move below traditional ranges.** Hyperscaler cash return on cash invested (CROCI) is implied by our analysts' forecasts to be moving down in coming years, though (close to but) not to levels that are below the low end of the 2014-24 range. Notably, we have seen recent management commentary that the present value impact of accelerating capex deployment can offset reductions in capital efficiency that may result from a speedier deployment/project selection. This may be true, particularly for companies whose investments translate into favorable corporate returns (ROCE, CROCI). We note, however, that this argument was used by managements extensively during the shale innovation cycle as the basis for increased drilling activity which, in a commoditized business, weighed on prices that negatively impacted the cash flow from both new and legacy supply.

In our view, the inflection into the Execution / Efficiency phase would require clearer evidence of demand becoming defined and constrained, financial flexibility tightening — particularly among AI pure-plays, and/or more meaningful

degradation in corporate returns — which would shift investor focus decisively from thematic exposure toward stock selection via company-specific growth and differentiated corporate returns. We expect investors will continue to debate where value creation from AI will be seen and if hyperscalers will see improved returns or will slow spending.

Exhibit 18: Analysis of shale's life cycle phases suggests the most meaningful multiple expansion occurs during the Appraisal / Hopes & Dreams Phase; stock-picking over thematics key for the Execution & Efficiency Phase
Innovation Life Cycle Phases applied to US Shale and AI/Data Centers



Source: Goldman Sachs Global Investment Research

Exhibit 19: We expect to remain in the sweet spot for Infrastructure and Risk Mitigation investment in 2026 with thematic investment defined by AI's Life Cycle Phase and perceived levels of local/global supply outage risk

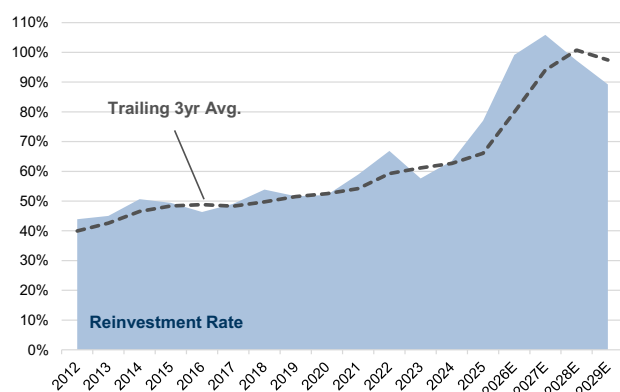
Impact to investment strategy based on whether AI is in Appraisal vs. Execution phase and the level of confidence in interdependency vs. need for redundancy of supply chains

		'Circle of Trust' Size: Geopolitical and Corporate Risk Emphasis	
		Wide: Interdependency	Narrow: Redundancy
AI Life Cycle Phase	Appraisal	Power/Water Infrastructure outlook	Positive
		Tech spending impact from AI efficiencies	Unchanged or higher
		Industrial expansion pace	Limited
		Power Demand outlook	Moderate growth
		Labor flexibility	Balanced
		Critical Materials Urgency	Moderate
		Investor focus on N-T Earnings vs. L-T value	Mixed
		Investor focus on Quality	Moderate
	Execution	Power/Water Infrastructure outlook	Favorable
		Tech spending impact from AI efficiencies	Negative revisions
		Industrial expansion pace	Limited
		Power Demand outlook	Slight growth
		Labor flexibility	Risk of oversupply
		Critical Materials Urgency	AI demand driven
		Investor focus on N-T Earnings vs. L-T value	Earnings
		Investor focus on Quality	Elevated

Source: Goldman Sachs Global Investment Research

Exhibit 20: Hyperscaler reinvestment rates are forecast to surpass 100% in 2027E

Reinvestment rate (capex + R&D as percent of operating cash flow + R&D) for hyperscalers, 2012-2029E

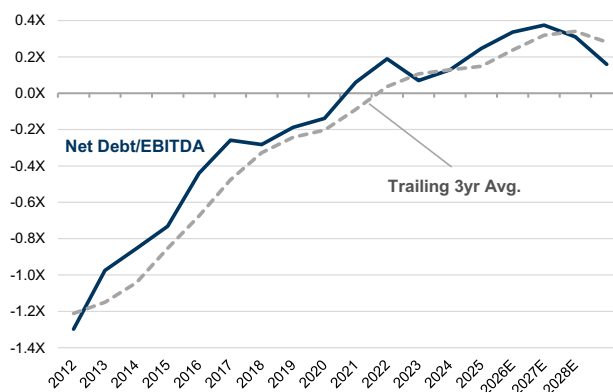


Hyperscalers include Google, Microsoft, Meta, Amazon, Oracle, Baidu, Tencent, Alibaba; Oracle, Baidu, Tencent and Alibaba estimates only extend through 2028E at present

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

Exhibit 21: Hyperscalers have seen their Net debt/EBITDA steadily increase over the past 15 years, though to levels our credit and equity teams still consider low

Net debt/EBITDA for hyperscalers, 2012-2029E

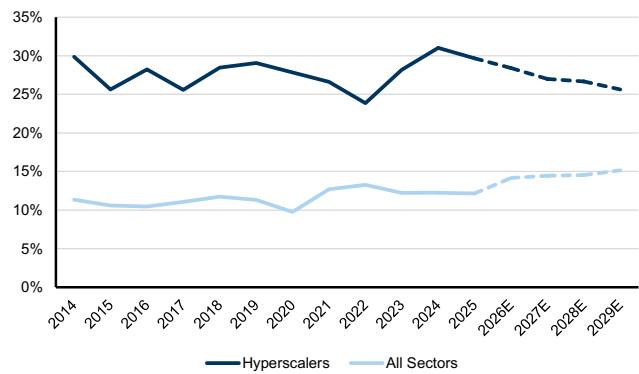


Hyperscalers include Google, Microsoft, Meta, Amazon, Oracle, Baidu, Tencent, Alibaba; Oracle, Baidu, Tencent and Alibaba estimates only extend through 2028E at present. Net debt and EBITDA used in calculations are from corresponding calendar years.

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

Exhibit 22: Corporate returns for hyperscalers have fluctuated between 24%-31%; analyst forecasts imply moderation through 2029E, though (close to but) not to lows from 2014-24

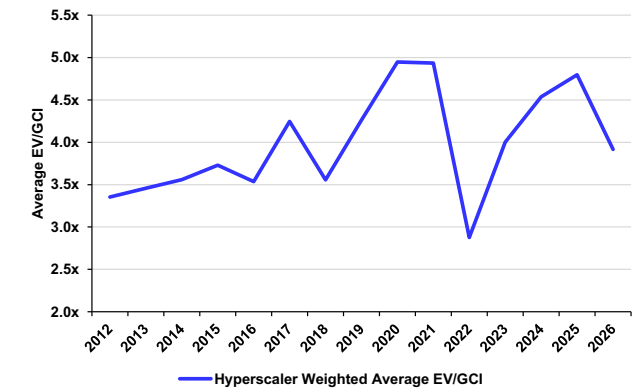
Annual weighted-average cash return on cash invested for eight global hyperscalers



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

Exhibit 23: Hyperscaler EV/gross cash invested multiples has tracked closely with corporate returns

Weighted-average EV/gross cash invested multiples at year-end (2026 as of August 4) for hyperscalers



Source: Company data, Goldman Sachs Global Investment Research

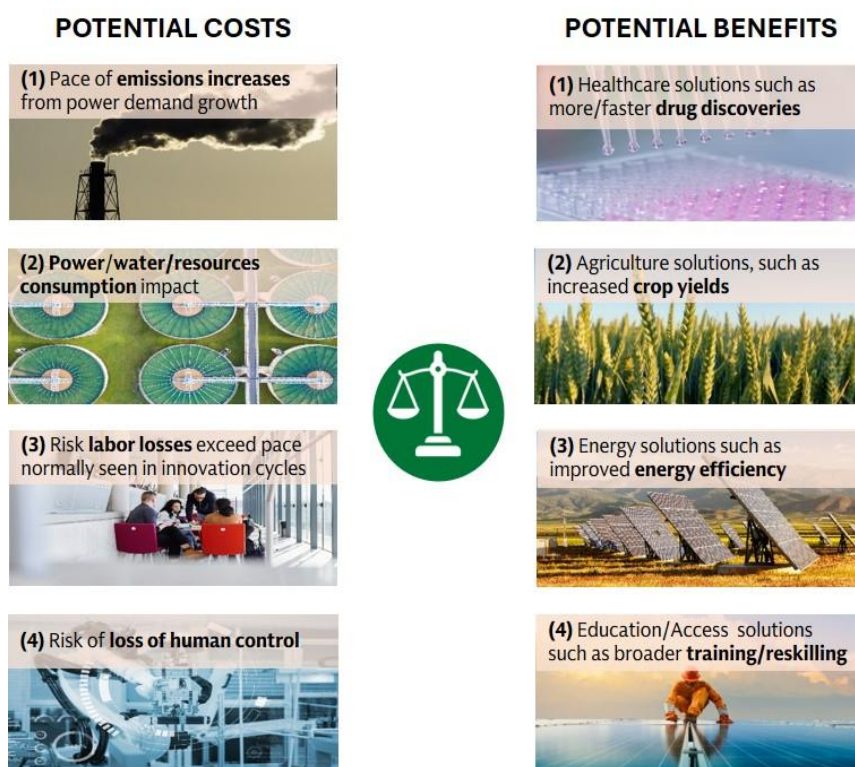
AI through a Sustainability lens: Considering the potential net impact

We believe Sustainable Investors will increasingly look at AI through the lens of the value of AI-driven Sustainability benefits less the value of AI-driven Sustainability costs. The sharp increase in hyperscaler capex + R&D combined with AI's rising demands for power and its associated externalities are focusing investors on how material AI solutions could become. We see the growth in power consumption from data centers by the end of the decade will represent the equivalent of adding another top-10 power consuming country. This driving two key investor areas of focus:

- What will be the value of AI's solutions, and what returns will that provide those making AI investments?
- From a sustainability perspective, how will the social and environmental value of AI's solutions compare to the cost of the growth in data center emissions?

Exhibit 24: AI through a Sustainability lens will likely be judged by the corporate and social value of benefits less costs

Key Sustainable Development Goal-based implications from AI



Source: Goldman Sachs Global Investment Research

Potential AI costs that could hinder Sustainable Development Goals

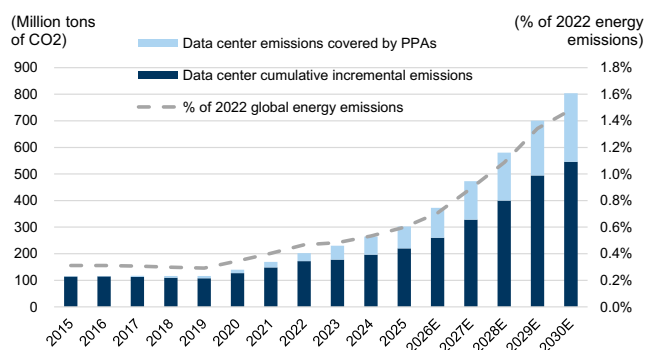
- **The impact of emissions increases to source power demand growth.** Our recent increase in data center power outlook drove upward revisions to our outlook for data center emissions, even as power purchase agreements from technology companies for low-carbon power have remained strong. We continue to expect an all-of-the-above approach to power sourcing based on relative economics, parts

availability, time-to-market considerations and long-term decarbonization objectives. We assume thermal power (largely natural gas) sources a majority of the data center power growth through 2030. However, power purchase agreements (PPAs) for renewable + nuclear power signed by technology companies has remained strong, rising 17% in 2025 yoy. Our latest forecasts imply carbon dioxide emissions increase by ~370 mn tons (+210%) in 2030 vs. 2023 levels, the equivalent of 1.0% of global energy emissions.

- **The impact of power/water/resources consumption on broader customer availability and prices.** As we highlighted earlier, there is meaningful pushback in the US towards data center development based in part on affordability/reliability of power and water. Sustainable investors will likely assess any broader consumer price/reliability impact in addition to any non-emissions-related land use impact from the additional power, water and resources (critical materials) needed for AI development. As we highlighted earlier, we see a power/water tradeoff depending on cooling technologies data centers deploy which may be limited by ambient conditions (heat, humidity, drought). As we have previously written, AI development may hasten a supply crunch for critical materials which alongside reliability/security priorities may accelerate deployment of circular solutions such as recycling and increased scrap usage.
- **The risk of labor losses that may exceed the pace normally seen with innovations.** Innovation cycles have long driven labor displacement, and we believe Sustainable investors will weigh whether potential job losses relating to AI will move at a slower vs. faster pace than past cycles (recent academic data suggests AI is following a similar trend). Our Economics Research team believes AI-related job losses will lead to a meaningful amount of labor displacement, we continue to expect that labor market headwinds will be temporary. Key to this view is our Economists' expectation that over the long run AI will create many new jobs even as it destroys existing ones. We have highlighted expectations for labor displacement relating to AI — pockets of oversupply and pockets of undersupply. As an example of undersupply, the combination of demographic shifts as well as historical disincentives towards careers in high voltage electricians and other related jobs requiring multi-year skilling are driving labor as a key constraint to data center development for now.
- **The risk of loss of human control.** As we wrote in our 2023 report, AI's Sustainable Solutions: Getting from Risks to Opportunities, the highest order of potential impacts includes more extreme tail risks of societal destabilization and disaster scenarios, such as the manipulation of elections, political repression, or automated warfare. Some AI-related tail risks linked with the potential emergence of artificial generalized intelligence (AGI) could lead to scenarios where humans lose control of machines. Compared with prior technology revolutions, AI may be unique in holding an especially wide range of potential consequences that we are not yet able to fully envisage. Recent breakouts of experimental models from testing environments at several AI model developers serve to illustrate this unpredictability. To mitigate these risks, creators of AI models will be pressed for transparency and accountability. This

would include mechanisms to alert users to AI-generated content and authorship ('watermarking'), warning labels, and disclosures of how the systems are trained and how they work. Voluntary commitments from creators are already being made including the enablement of independent audits and third-party testing, while corporate users are putting into place frameworks for ethical use of AI. These potential mitigants complement potential for regulation and enforcement efforts.

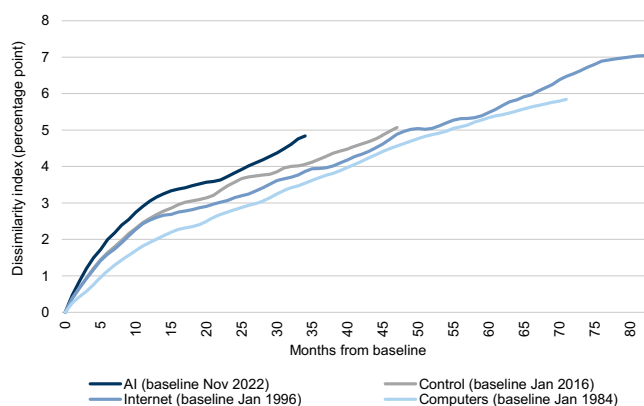
Exhibit 25: We see data center emissions increasing ~210% by 2030 vs. 2023 levels (+1.0% increase in global energy emissions), net of impact of power purchase agreements (PPAs) from technology companies
Carbon dioxide emissions in millions of tons (LHS); percent of 2022 energy emissions (RHS)



Source: IEA, Goldman Sachs Global Investment Research

Exhibit 26: AI's influence on the labor market follows similar trends with prior technological changes

Changes in the occupational mix over different periods of technological change



Source: The Budget Lab at Yale, Data compiled by Goldman Sachs Global Investment Research

Potential AI benefits that could advance Sustainable Development Goals

- **Healthcare — Accelerating discovery and more efficient care.** AI-driven acceleration of drug discoveries — both via a higher success rate and a swifter process — has potential to unlock significant value for the sector where there are increased debates on returns from R&D. We also see higher/faster drug discoveries playing a prominent role in debates around the broader corporate and social value of AI relative to costs. As discussed in [Byte-ology: Quantifying AI's value creation in drug development](#) (February 2026), our Biotechnology team has linked AI to an increase in the success rate of drug discoveries by 370 bps (implying 28 new drug discoveries per year) and a reduction in testing and development timeline that reduces years to first revenue to about 10 from 13. We see AI-driven acceleration applied to drugs entering the pipeline over a 10-year period potentially adding ~\$83-\$412 bn of corporate present value (PV) depending on discount rate, representing 2%-12% of US pharmaceutical and biotechnology covered company market cap. There are multiple additional healthcare related efficiency solutions (including automation) that have potential to provide greater customer flexibility, especially for the [increased number of elderly in coming years](#).
- **Agriculture — Improving yields and reducing waste.** AI-enabled applications stand to improve agricultural outcomes all the way from enhanced insights into what

to plant and when to improve logistics that reduce time-to-market for perishable goods. Precision agriculture — data driven approaches to farming (crops & livestock), is the broadest category where leveraging AI can help to improve yields and reduce waste. However, beyond the myriad of AI applications that fall under the precision ag umbrella, AI also stands to help improve agricultural supply chain safety, speed and transparency. We believe Agricultural efficiency solutions will increasingly be in demand given the potential impact from elevated physical risk on the supply of key global food staples such as corn, rice, soybeans and wheat as highlighted in our February 2026 [Enabling Agricultural Resiliency](#) report.

- **Energy — [Optimization](#) and efficiency in power generation/physical assets and consumption efficiency.** As part of broader potential AI efficiency/productivity solutions, the ability to consume less energy (and water and resources) without negatively impacting quality of life is likely to be a key focus among Sustainable investors and, given inflationary pressures/affordability concerns, among generalist investors as well. AI holds promise for being a contributor to both climate mitigation and adaptation in a wide range of applications, including: renewable energy optimization (e.g., weather forecasting, operational scheduling, battery storage optimization); physical asset and power use optimization (e.g., dynamic heating/cooling, data center efficiency, manufacturing efficiencies); and climate modeling.
- **Human Capital & Education:** [Reskilling](#), [Upskilling](#), [Interactivity](#) and [Personalization](#). Increasing adoption of advanced technologies such as AI create a growing need for educational platforms that enable ‘reskilling’ and ‘upskilling.’ We also anticipate greater demand for human capital management tools that can help identify and match rapidly shifting worker competencies with organizational needs (‘skills matching’).
- **Circular Economy:** AI has the ability reduce waste across various portions of the value chain. From optimizing resource use, reusability and recyclability in initial product/system designs to enhancing upstream suppliers/logistics and [operational resource efficiency](#) and enabling improved end-of-life materials collection, AI has broad potential to reduce material waste across many sectors of the economy. These savings can help to drive material environmental and economic benefits for constrained resource stocks like [critical materials](#) or [water](#).

Exhibit 27: Increased AI investment is further raising scrutiny of the extent to which AI is or will accelerate progress across a range of Sustainable Development Goals (SDGs); recent data increases our optimism on success rates/pace of drug discoveries



Source: Goldman Sachs Global Investment Research

Quantifying AI Sustainability impact: Social cost of data center emissions vs. AI's social value

Our conversations with investors have suggested increased support for a benefits-vs.-costs approach, though with still some debate both about framework and process. The easiest way to measure AI's benefits would come if there are offsetting emissions reductions (more efficient consumption trends or competitive supply cost for round-the-clock energy supply), in our view. But in the absence of direct emissions reductions enabled by AI, the expected surge in data center demand and the contribution from AI/data centers to higher emissions will likely lead to a value assessment. Measuring the tradeoff of higher power consumption for enabled benefits may not be as easy as an avoided emissions analysis where avoided emissions are compared to actual emissions. In this case, the tradeoff may need to be value based — value enabled vs. cost of increased emissions.

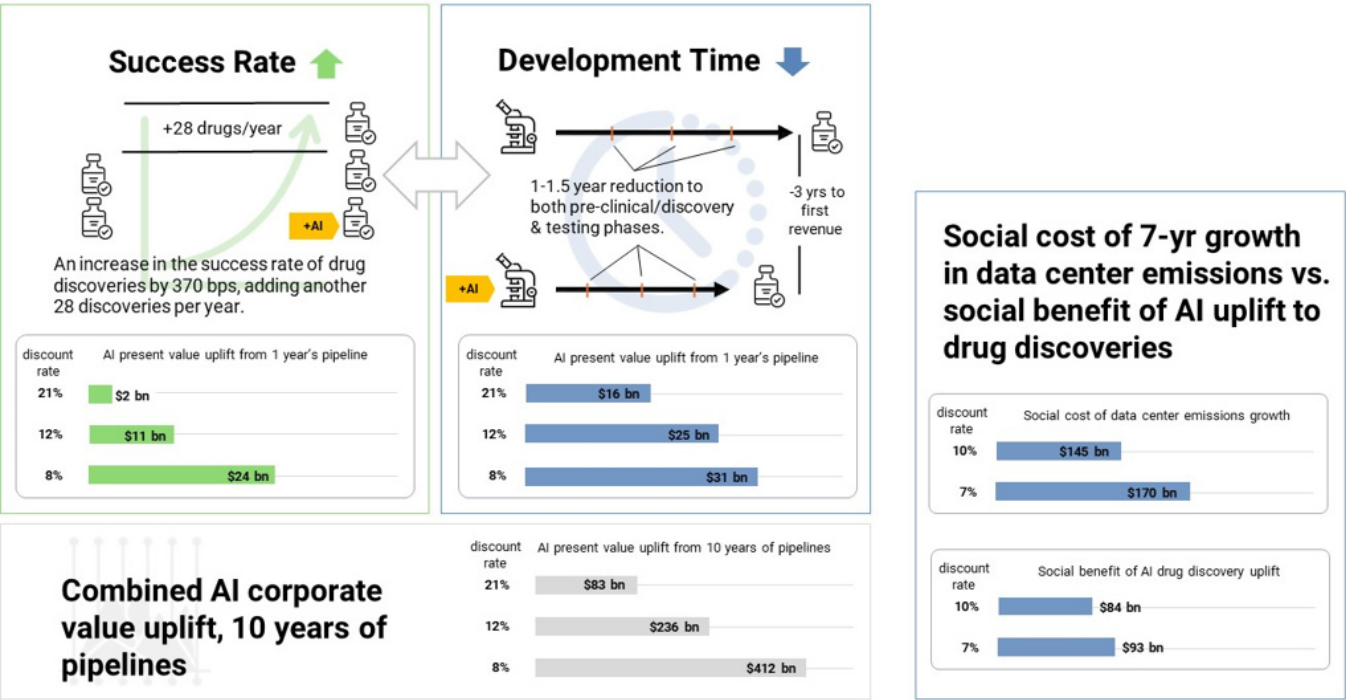
- In determining the cost of emissions, the \$/ton social cost is an area of debate. The US EPA after a November 2023 update to its framework applies a \$190 per ton social cost of carbon dioxide emissions, and a September 2022 article in Nature argues for a \$185 per ton cost. Using a \$190 per ton social cost of carbon of about 285–290 million tons of expected data center emissions increase in 2030 vs. 2023 would suggest a present value at a 7%–10% discount rate range of about \$140–\$170 bn for the social cost of the incremental emissions from data centers (Exhibit 20). We

recognize that there is significant debate about the value and use of social cost of carbon analysis and that there may be other costs that investors, governments, corporates and households may choose to value.

- As we highlighted in our February 2026 report, Healthcare & GS SUSTAIN: Byte-ology: Quantifying AI’s value creation in drug development, we see potential for \$84-\$93 bn of social present value from a 7-year period of AI-driven increased pace/success rates of drug discoveries at levels consistent with recent results our Biotechnology team links to AI that would imply a pace of 28 new drug discoveries per year. This alone represents a high percentage of the \$140-\$170 bn social cost from data center incremental emissions.

Among AI SDG-advancing potential solutions, drug discovery/process potential comes up the most in investor discussions. But feedback from discussions with Sustainable investors suggests there is neither confidence in re-rating stocks for AI social value potential nor in what the value uplift could be.

Exhibit 28: AI Pervasiveness: Recent data suggests AI is helping to boost both pace and success rate of drug discoveries Estimated corporate value and social value from AI-driven acceleration of rate and pace of drug discoveries



Source: Goldman Sachs Global Investment Research, FDA, BGC, NIH, Tufts, HHS, DOE

AI governance likely to be a rising area of engagement focus among investors

While safety (i.e., injuries, fatalities and lost hours) have long been a focus of investor diligence — particularly in certain sectors — we believe increased cyberdependence is likely to increased demands for numeric metrics to measure cybersafety. Global disclosure has been somewhat limited and not consistent. However, there have been moves by the SEC for companies to disclose Material and Non-Material Cybersecurity incidents in addition to cybersecurity governance, as well as AI regulation

already in effect in Europe. We believe broader AI-related investor engagement will center around how boards are overseeing and managements are measuring and mitigating the key risk factors above, with a particular focus on loss of human control, in-house human capital retraining and how companies are developing human oversight expertise.

Investor engagement strategies. We see three potential angles of investor engagement questions for corporate managements related to AI, as introduced in our March 2025 Sustainable investor guide to AI regulations and engagement report: (1) Development, (2) Risk Management and Compliance, and (3) Governance and Implementation.

Development:

- Is the company preventing against the inadvertent development of potentially harmful algorithms?
- How is the company prioritizing ethical use of AI in product development?
- How is the company addressing potential risks of discrimination and biases in their systems?
- Particularly with generative AI applications, how is the company addressing copyright protections and rising concerns of intellectual property infringement?

Risk Management & Compliance:

- Describe the company's risk management systems for AI and how they identify and estimate potential risks and implement risk management measures.
- Does the company have a team dedicated to AI regulatory compliance and risk? Describe its role and chain of accountability.
- What are the regulatory requirements for the company's AI products, according to its risk level categorized by the AI Act?

Governance & Implementation:

- Describe the company's data governance procedures, user transparency and human oversight.
- How is the company training or re-skilling employees to be competent with AI systems?
- Does the company have codes of conduct related to AI use cases and how is AI-related risk and performance measured?
- How is the company sourcing/training future managers with sufficient expertise, perspective and judgment to drive execution and strategic decision making?

Disclosure Appendix

Reg AC

We, Brian Singer, CFA, Brendan Corbett, Xavier Zhang, Evan Tylanda, CFA, Carly Davenport, Michael Ng, CFA, Eric Sheridan, Gabriela Borges, CFA and Alberto Gandolfi, 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.

Unless otherwise stated, the individuals listed on the cover page of this report are analysts in Goldman Sachs' Global Investment Research division.

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