CPUC Proceeding: A.24-11-007

Exhibit: TURN-01E

Date: June 30, 2025

TESTIMONY OF THE UTILITY REFORM NETWORK ADDRESSING PROPOSED RULE 30 RATEPAYER IMPACTS AND RELATED ISSUES

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Revised July 10, 2025

TURN

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I. INTRODUCTION

This testimony is sponsored by TURN Senior Policy Expert, Jennifer Dowdell and addresses potential ratepayer impacts related to PG&E's proposed Rule 30 and policy recommendations by TURN to mitigate these impacts.

Rather than continuing to address transmission interconnection on a customer-by-customer basis, PG&E's proposed Rule 30 application seeks to create standardized conditions for interconnecting large transmission level customers, much as Rule 15[1] and Rule 16[2] apply to interconnections at distribution level. PG&E's application explains that when it interconnects transmission customers it must file a separate application for each interconnection agreement, resulting in contracting costs and delays in interconnecting the customers.[3]

TURN understands that interconnection under proposed Rule 30 does not presume any specific tariff under which a Rule 30 customer will receive service from PG&E other than that the applicable tariff must be one available to transmission level customers. Rule 30 addresses *only* how the costs of customer-specific interconnection facilities will be advanced by the customer and potentially refunded if the customer meets its expected load over the first ten years of interconnection. While Rule 30 uses the Base Annual Revenue Calculation (BARC) method to determine the appropriate amount of interconnection costs that should be refunded to the customer, it does not address specific rates or cost allocation issues.

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[1] PG&E Application for Approval of Electric Rule No. 30 for Transmission-Level Retail Electric Service, November 21, 2024, p. 1.

[2] Electric Rule No. 16 "is applicable to both (1) PG&E Service Facilities that extend from PG&E's Distribution Line facilities to the Service Delivery Point, and (2) service related equipment required" by the customer to receive electricity service from PG&E. (Source: Electric Rule 16, sheet 1, available at: https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_RULES_16.pdf.)

[3] PG&E Application, p. 1.

Although PG&E's cost recovery and allocation across customer classes is traditionally addressed in GRC Phase 2 proceedings, the Scoping Memo in this proceeding appropriately recognizes the need to ensure that existing ratepayers are kept whole and not unreasonably subsidizing new Rule 30 customers.[4]

Below is a breakdown of PG&E's potential interconnection customers by business type.

Table 1: Anticipated Rule 30 Customer Load by Business Type.[5]

Site Type	2025, MW	2026, MW	2027, MW	2028, MW	2029, MW	2030, MW
Data Center	21.5	313.8	709.8	3,967.4	5,159.9	5,890.2
EV	0	26.4	28.4	37.1	42.1	50.7
Government	44	44	68.8	68.8	68.8	95.8
Industrial	0	8	59	60	61	69.5
Manufacturing	30	102.8	123	150	162	190.2
University	0	10	12	67	88.8	98.8

This is especially important because data centers account for many potential new Rule 30 customers. In fact PG&E states that roughly 67% of its expected Rule 30 customer load would be from data centers.[6] While there are a variety of data center business models that differ in their scale, preferred client base, and computing technology; all data center equipment consists primarily of computer servers (often thousands), which generate significant heat from their operations and must been kept cool 24/7 in order to function.[7] The continuous computations and associated need to cool the servers drive very high load factors, even as compared to other large industrial customers, of close to 100%.[8] Energy consumption is said to make up between 40% and 70% of a data center's operating cost.[9]

[4] A.24-11-007 Scoping Memo, dated March 11, 2025, p.6-7.
[5] DR_TURN_001-Q007.
[6] PG&E Testimony, November 21, 2024, p. 1-5.
[7] Source: IBM What is a data center: https://www.ibm.com/think/topics/data-centers
[8] Traditional large industrials such as oil refineries have load factors of 65-70%. For its illustrative calculations, PG&E used 85%.
[9] *Borenstein, Severin.* "Can Data Centers Flex Their Power Demand?" *Energy Institute Blog, UC Berkeley, April 14, 2025*, https://energyathaas.wordpress.com/2025/04/14/can-data-centers-flex-their-power-demand/

Currently, data centers account for approximately 2% of California's electricity demand, but this number is expected to grow.[10] In June 2024, PG&E anticipated 26 data center projects totaling 3.5 GW to come online in the Bay Area by 2029. This included three potential customers that would need at least 500 MW of capacity 24 hours a day.11 In PG&E's supplemental testimony it increased its projection to 34 projects greater than 4.0 MW, and 4.0 GW.[12] For purposes of its Testimony TURN does not distinguish between these figures except to note that PG&E's projections are growing, which will only magnify Rule 30 effects on ratepayers. Whether PG&E projects 3.5 GW or 4.0 GW, or even more, these figures are staggering. TURN's concerns with Rule 30 stem from the fact that these proposed data centers are: 1) many times larger than most typical industrial customers; 2) in aggregate they represent significant new electrical load at a high load factor; and 3) concentrated in a relatively small geographical and electrical transmission area. For these reasons, new transmission level data center interconnections will have impacts on the electricity grid, generation, and costs for other customers.

A. <u>Data Centers are Uncommonly Large Individual Customers (Scoping Memo Issue 3.e)</u>

Data center customers connected under Rule 30 are expected to be multiple times larger than traditional industrial loads. PG&E cites projects from 30 MW to 75 MW in its illustrations.

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[10] Branton, Steve et al., "Demonstration of Low-Cost Data Center Liquid Cooling." California Energy Commission, June 14, 2024. https://www.energy.ca.gov/publications/2024/demonstration-low-cost-data-center-liquid-cooling

[11] "Power-hungry AI data centers are raising electric bills and blackout risk" LA Times, Melody Petersen, August 12, 2024, available at: https://www.latimes.com/environment/story/2024-08-12/california-data-centers-could-derail-clean-energy-goals#:~:text=Experts%20warn%20that%20the%20frenzy%20of%20data,say%2C%20also%20increases%20the%20risk%20of%20blackouts

[12] PG&E Testimony, p. 1-4.

Table 2 provides a comparison of Watts per square foot for traditional large customers. Compared to colleges, shopping centers, and hospitals, data center load is 12 to 18 times higher. *Even compared to indoor cannabis cultivation, data centers range from 1.5 times to 2 times higher than the typical load of such facilities.*

Table 2: Rule 30 Customer Relative Sizes[13]

Customer Type	Historical Range of Maximum Watts per Square Foot
Colleges	4.5 - 6.1
Hospitals	5.5 – 7.7
Offices	4.0- 5.0
Shopping Centers	4.5 - 6.1
Greenhouse Cultivation	14.0
Indoor Cultivation	46.0
Data Centers	75.0-100.0

B. <u>Data Centers Represent Significant Aggregate Loads (Scoping Memo Issue 3.e)</u>

Data centers typically operate at higher load factors (85%-100%) than traditional large industrial customers, which TURN understands typically have load factors that range from 50%-70%. This results in not only high demand, but also very high kWh usage. Table 2 below shows PG&E's projected data center demand and usage based on the 40 active applicants for

[13] Source: DR_CalAdvocates_004-Q012.

transmission level service noted in its testimony with a demand of 4MW or greater based on assuming 100% of projects are built.

Table 3: PG&E Projections of Data Center Demand[14]

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
MW	30	299	1,225	3,451	5,183	6,489	7,764	7,974	8,236	8,368	8,396	8,396	8,422	8,422	8,422	8,422	8,173
GWh	210	2,095	8,586	24,185	36,325	45,474	54,410	55,878	57,717	58,641	58,837	58,837	59,019	59,019	59,019	59,019	57,278

PG&E projects incremental annual aggregate usage from data centers ramping up from 8,500 GWh in 2026 to more than 54,000 GWh by 2030 and to 59,000 GWh by 2035.[15] Based on PG&E's projections data center incremental annual usage could grow from roughly 2000 GWh currently to nearly 60 GWh by 2035. This load is likely to be served under B20-T absent a new large customer tariff. [16]

For comparison, in 2025 PG&E anticipates the total load of all of its largest customers (bundled and CCA) 2025 to be roughly 14,000 GWhs.[17] A subset of these, PG&E's current bundled B20-T customers which presumably would include new Rule 30 customers is roughly only 2,000 GWhs,[18] a fraction of the anticipated Rule 30 load.

C. <u>Data Center Load is Geographically Concentrated (Scoping Memo Issue 3.e)</u>

PG&E's data center projects are heavily concentrated in the South Bay, near Santa Clara and San Jose where 60% of all data centers in Northern California are located and where 40% of all of

[14] DR_CalAdvocates_004-Q018.
[15] DR_CalAdvocates_004-Q018.
[16] PG&E's B20-T requires customers have demand of at least 1 MW, where typical data centers of 75 MW would have demand 75 time greater than that minimum.
[17] PG&E 2025 AET Advice Letter 7469-E, dated December 30, 2024.
[18] 2025 AET Advice Letter 7469E, dated January 23, 2025, attachment 1b, Bundled Customers, p. 2.

California's more than 300 data centers are.[19] A breakdown of current data center locations in Northern California is shown below.

Table 4: Data Center Locations in Northern California

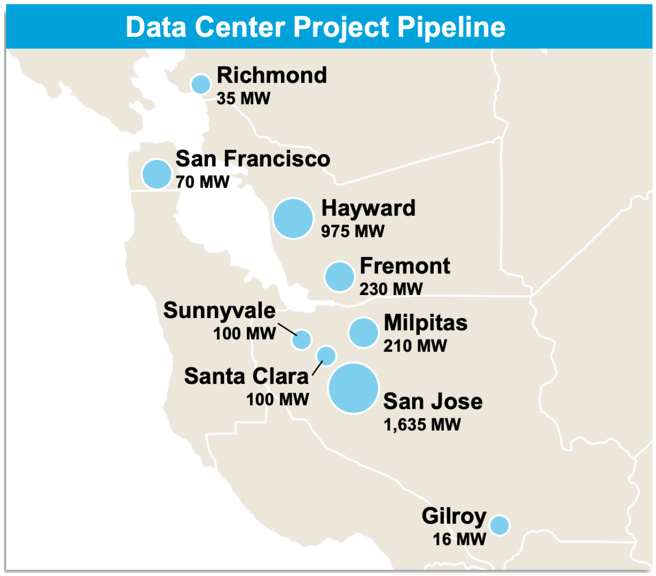
Northern California Data Centers	Count
San Jose	44
Fremont	6
San Francisco	15
Santa Clara	75
Palo Alto	3
Sacramento	22
Oakland	1
Fresno	3
Mountain View	1
San Luis Obispo	4
Modesto	2
Emeryville	2
Goleta	1
Santa Cruz	1
Hayward	4
Stockton	3
Bakersfield	2
Total Data Centers:	**189**

Source: Data Center Map.com, available at: https://www.datacentermap.com/usa/california/

PG&E explains that San Francisco Bay Area is one of eight primary data center markets in the US, attractive for proximity to Silicon Valley, the fiber network, and California's clean energy supply.[20] Table 5 maps the proposed locations of 26 new Rule 30 data center projects.

[19] California Data Center Map, available at: https://www.datacentermap.com/usa/california/
[20] "2024 Investor Update: Delivering For Customers and Investors." PG&E, June 12, 2024, p. 20. https://s1.q4cdn.com/880135780/files/doc_presentations/2024/June/2024-Investor-Update-Presentation_Final.pdf.

Table 5: Projected Rule 30 Data Center Projects[21]



Given the foregoing project size, rate of growth and geographical concentration, it is hard to conceive that there will not be increased costs for existing ratepayers both from the transmission grid upgrades and the overall need for generation capacity to provide the necessary kilowatt hours. Such impacts are foreseeable and have been observed in other states and jurisdictions. Based on the experience of other utilities where data centers have proliferated, Rule 30 as proposed is likely have a negative impact on affordability for existing ratepayers.

To protect the interests of existing ratepayers, the Commission should take action in this proceeding to modify areas in PG&E's proposed Rule 30 tariff where existing ratepayers may bear additional costs (rather than savings) due to these new customers. In addition to the TURN-recommended modifications to Rule 30 in this proceeding, TURN urges the Commission to require PG&E to provide a large customer rate schedule for Rule 30 customers in its 2025 GRC Phase 2 (A.24-09-014), which is currently an open proceeding. TURN urges the Commission to grant Cal Advocates motion in (A.24-09-014) to include rate structures for large-load

[21] "2024 Investor Update: Delivering For Customers and Investors." PG&E, June 12, 2024, p. 20. https://s1.q4cdn.com/880135780/files/doc_presentations/2024/June/2024-Investor-Update-Presentation_Final.pdf.

transmission-level customers in the scope of that proceeding.[22] The Commission should not authorize Rule 30 absent provisions in the interconnection rule and an appropriate tariff or cost allocation mechanism to prevent other customers and customer classes from subsidizing the costs to serve an unprecedentedly large number and volume of transmission level customers.

II. SUMMARY OF TURN RECOMMENDATIONS

In considering PG&E's Rule 30 proposal, the Commission should take lessons from other states and jurisdictions that have experienced rapid growth in large transmission-level customers and exercise caution. Given the potential for cost shifts from Rule 30 customers to non-participants, TURN does not recommend any departure from the case-by-case exception process that PG&E has used to connect large loads. The Commission need look no further than the experience of Silicon Valley Power for an illustration of how an influx and proliferation of data centers in a concentrated area can drive up costs to non-participants and threaten affordability.

If the Commission approves Rule 30, it should adopt TURN's recommended modifications to PG&E's proposal. These are summarized below and more fully addressed in Section IV.

- The BARC formula used to compute the amount of refund a Rule 30 customer receives should be modified as proposed by Cal Advocates in this proceeding.
- Regardless of who constructs the interconnection facility, the costs included in rate base should be the lower of PG&E's projected construction cost, or the developer's projected construction cost.
- Rule 30 participants should be required to enroll in a mandatory demand response program appropriate for large transmission-level customers developed or approved in A.24-09-014, or other appropriate Commission proceeding.
- Rule 30 should be modified to require that customers pay all projected incremental revenues over the 10-year contract, regardless whether they achieve full ramp-up of electricity demand at the facilities.

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[22] See Public Advocates Office Motion to Amend the Scoping Memo to Include Issues from Application 24-11-007.

- Rule 30 Tariff customers with load factors greater than 70% should be required to include 4-hour battery storage capacity or other behind the grid clean energy capacity equal to 100% of their projected load. This storage capacity should be dispatchable by PG&E and may be refunded along with interconnection under the corrected BARC process.
- In this proceeding and PG&E's GRC Phase 2, the Commission should take notice of the actions in Georgia, Ohio, Michigan and Oregon to protect ratepayers from bearing interconnection and grid upgrade costs incurred primarily to serve data centers.
- Any final interconnection Rule approved in this proceeding should inform applicable tariffs for SDG&E, SCE and other investor owner California electric utilities.

III. PG&E'S RULE 30 PROPOSAL IS MORE LIKELY TO RESULT IN RATEPAYER COSTS RATHER THAN SAVINGS AND MORE HARMS THAN BENEFITS (SCOPING MEMO ISSUES 1, 2 & 3)

PG&E states that Rule 30 provides "numerous benefits."[23] PG&E states than in addition to other facility related benefits, existing electric customers also receive: (1) substantial potential bill reductions from the revenues received from new transmission level retail electric customers interconnecting at transmission level voltages; (2) financial protections; and (3) reliability benefits.[24] Finally, PG&E states that not just bundled customers will benefit from the astonishingly large addition of primarily data center load anticipated under Rule 30, but instead "Electric Rule 30 will benefit all customers that use the electric distribution and transmission systems, including Community Choice Aggregation customers and Direct Access customers."[25]

PG&E presents two methods of demonstrating that existing ratepayers are not monetarily harmed by (or indeed benefit from) its proposed Rule 30 Tariff. These are: 1) the Base Annual Revenue Calculation (BARC) method currently employed for Rule 15/16 distribution level customers;[26] and 2) a calculation of potential bill savings.[27] PG&E asserts that there are also

[23] PG&E Testimony, pp. 1-13 to 1-15.
[24] PG&E Testimony, p. 1-15.
[25] PG&E Testimony, p. 1-15.
[26] PG&E Testimony, p. 2-12.
[27] PG&E Testimony pp. 3-5 to 3-8.

grid benefits that could arise from the addition of these large customer interconnection facilities.[28] However, PG&E fails to fully explain or quantify these benefits. None of PG&E's demonstrations demonstrate that existing ratepayers will not be harmed by Rule 30 under realistic assumptions.

Neither PG&E's sample BARC calculation nor its illustrative bill savings are based on realistic costs that could offset incremental revenue requirement contribution from data centers. PG&E's assumptions include the low end of the potential range for transmission and distribution upgrade costs. PG&E's analysis does not consider any costs of new generation even though it is likely Rule 30 customers could trigger new generation and storage costs. Most problematic is PG&E's position that, for transmission network upgrade costs (type 4 facilities), prior FERC decisions support ratepayer funding for these costs regardless of whether the interconnecting new Rule 30 customers to be served by the type 4 facility provide a benefit to existing customers.

A. Rule 30 Customers May Trigger Significant Costs for Future Grid Upgrades (Scoping Memo Issues 1, 3.e, 3.f & 3.k)

Recent projections by Standard and Poor's (S&P) Credit Rating Agency anticipate that although data center growth is a new and evolving development in regulated utility business, the associated capital spending to enable the interconnection of data center loads could increase nationwide estimates of capital spending by 15%, including both interconnection costs and grid upgrades to support data center load.[29] Currently 75 of the 314 data centers in California are

[28] These appear to primarily be substation and switching equipment which are purchased by Rule 30 customers and therefore will be available for the system. "The trnsmission substations and switching stations installed to provide service to transmission-level customers under Rule 30 can also play a key role in developing and maintaining a reliable, resilient, and interconnected electric grid." (PG&E Testimony, p. 4-2).

[29] S&P Global Ratings, Industry Credit Outlook 2025, North American Regulated Utilities, Capex and climate change pressures credit quality, January 14, 2025, p. 6.

located in Santa Clara.[30] In Santa Clara (which is served by Silicon Valley Power), electricity rates have historically increased by 2% to 3% a year, but they jumped by 8% in January 2023, another 5% in July 2023 and 10% in January 2024.[31] Silicon Valley Power's electric rates, which were once 40% of PG&E's rate, rose rapidly due to heavy spending on transmission facilities and other infrastructure to accommodate data center load.[32] Certainly, once energy infrastructure is in place increasing usage through new load and spreading fixed costs over more kWh of delivered energy makes basic economic sense, but only if the new kWhs can be added without significant additional investment.

For PG&E the potential for grid upgrades comes after a record of continual growth in capital spending and rate base on which shareholders earn their profit. From 2015 to 2024, PG&E's capital spending grew from 5.4 billion[33] to $10.6 billion,[34] nearly 100% over the past 10 years at an accelerating pace, with cumulative rate increases of 130%[35] over the same period. PG&E's projected annual spending is $12-13 billion from 2025 to 2028.[36] With weighted

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[30] California Data Centers, available at: https://www.datacentermap.com/usa/california/

[31] "Power-hungry AI data centers are raising electric bills and blackout risk" LA Times, Melody Petersen, August 12, 2024, available at: https://www.latimes.com/environment/story/2024-08-12/california-data-centers-could-derail-clean-energy goals#:~:text=Experts%20warn%20that%20the%20frenzy%20of%20data,say%2C%20also%20increases%20the%20risk%20of%20blackouts

[32] Id.

[33] PG&E Corporation First Quarter Earnings Call, May 4, 2016, slide 11, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2015/Q4/Earnings-Presentation-Q4-2015-FINAL.pdf.

[34] PG&E 2024 Fourth Quarter and Full Year Earnings Presentation, February 13, 2025, Slide 11, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2024/q4/Q4-24-Earnings-Presentation.pdf.

[35] Based on Non-CARE residential rates. Calculation January 2015-January 2024; (0.466-0.203)/.203=130% (Source: PG&E Annual Electric True-up filings).

[36] PG&E 2024 Fourth Quarter and Full Year Earnings Presentation, February 13, 2025, Slide 11, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2024/q4/Q4-24-Earnings-Presentation.pdf.

average rate base over CPUC and FERC roughly doubling from $32.6 billion[37] in 2015 to $63 billion[38] in 2024 and projected at $91 billion for 2028 of which 82% is "already authorized."[39]

PG&E has stated to investors that for each GW of data center load, PG&E anticipates spending between $0.5 billion and $1.6 billion in system capital (transmission and distribution investments).[40] Thus, based on PG&E's typical data centers cost illustrations of a 75 MW facility,[41] ratepayers might be asked to fund Type 4 transmission capital upgrades of $120 million for a single project. Facility Type 4 is PG&E's term for upgrades to the existing transmission system. Transmission reliability upgrades may be required as well as capacity. PG&E argues FERC has rejected the direct assignment of these costs to specific customers.[42]

These investments will go to significantly increase PG&E's rate base creating further challenges for affordability unless accompanied by sustained offsetting incremental revenues from data centers. These massive capital costs highlight the need for significant protections for existing ratepayers through provisions of Rule 30 and appropriate specific large customer rate schedules. Further, large data centers can increase or decrease load quickly and significantly (potentially by almost 100%) due to changes in computing demand from normal AI model

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[37] PG&E Corporation First Quarter Earnings Call, May 4, 2016, slide 12, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2015/Q4/Earnings-Presentation-Q4-2015-FINAL.pdf.

[38] CPUC jurisdictional rate base was $52 billion. (Source: PG&E 2024 Fourth Quarter and Full Year Earnings Presentation, February 13, 2025, Slide 11, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2024/q4/Q4-24-Earnings-Presentation.pdf.

[39] PG&E 2024 Fourth Quarter and Full Year Earnings Presentation, February 13, 2025, Slide 11, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2024/q4/Q4-24-Earnings-Presentation.pdf.

[40] "2024 Investor Update: Delivering For Customers and Investors." PG&E, June, 12, 2024, p. 23. https://s1.q4cdn.com/880135780/files/doc_presentations/2024/June/2024-Investor-Update-Presentation_Final.pdf

[41] Rule 30 Supplemental Testimony Work Paper 2.

[42] PG&E Supplemental Testimony, p. 43.

training operations and or currency price response in crypto mining operations.[43] Because data center infrastructure is mobile enough to relocate its facilities to meet its business interests, these upgrades run the risk of becoming stranded cost.

B. Rule 30 Customers May Trigger New Generation Needs (Scoping Memo Issues 3.e & 3.k)

Another area of concern is the sheer volume of energy required potentially 24/7 by data centers both individually and collectively. The frenzy of data center construction could delay California's transition away from fossil fuels and raise electric bills for non-participants. PG&E has stated that it expects its Bay Area Load to grow 30% by 2034 and by 50% by 2039.[44] TURN does not dispute that load growth can be positive for customers, but less so when load is added as a step function and drives exceptional energy capacity costs for other customers. As illustrated in the PJM energy capacity market area,[45] First Energy's CEO observes:

> "There is a disconnect between the timing of adding significant amounts of load, such as data center load, that can take about three years to develop and bring online, and building a power plant, which takes about six years to complete. So are our customers going to pay higher capacity auction prints (sic) for the next six years before any net new capacity shows up from the price signals that are being sent to this market?"[46]

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[43] Grid Strategies, Strategic Industries Surging: Driving US Power Demand, p. 18, available at: https://gridstrategiesllc.com/wp-content/uploads/National-Load-Growth-Report-2024.pdf

[44] A.24-03-009, Application of PG&E for Approval Under Public Utilities Code Section 851 To Lease Entitlements To Transmission Projects To Citizens Energy Corporation, p. 22.

[45] PJM is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia. See https://www.pjm.com/about-pjm.

[46] (Utility Dive "States should procure power supplies outside PJM capacity auctions: First Energy CEO, Capacity concerns come amid a surge in data center development with First Energy receiving more than 60 service inquiries larger than 500 MW this year," Ethan Howland, October 2024, available at: https://www.utilitydive.com/news/states-power-supply-pjm-capacity-auction-firstenergy-data-center/731588/).

Along with precipitating capacity spikes in the energy markets, data centers' demand for electricity also increases the risk of blackouts."[47] CAISO has already experienced rolling blackouts due to peak power shortages on August 14 and August 15, 2020, and since has maintained Flex Alert protocols to help prevent a recurrence.[48] The potential of data centers to consume any existing energy which is priced at marginal cost, while triggering and accelerating the need for new generation resources at total cost represents a genuine future cost to existing ratepayers that must be considered. For example, Entergy aims to spend $3.2 billion to build three large natural gas power plants with a total capacity of 2.3 GW in addition to grid upgrades to accommodate the huge jump in anticipated data center demand.[49] In response to competing needs for energy, Duke University research suggests that a near term mitigation may be limited curtailments of large loads. Duke's study cites "average curtailment times of about two hours which could be managed with the use of short duration batteries.[50] Duke estimates that limited curtailment of data center loads in CAISO could create between 4GW and 6GW of headroom for new load in CAISO at curtailments ranging from 0.25% to 1% of hours.[51] Further, through peak shaving, data centers may have the ability to participate in ancillary services, particularly those

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[47] "Power-hungry AI data centers are raising electric bills and blackout risk" LA Times, Melody Petersen, August 12, 2024, available at: https://www.latimes.com/environment/story/2024-08-12/california-data-centers-could-derail-clean-energy-goals#:~:text=Experts%20warn%20that%20the%20frenzy%20of%20data,say%2C%20also%20increases%20the%20risk%20of%20blackouts.

[48] California ISO Fact Sheet, available at: https://www.caiso.com/documents/rotating-power-outages-fact-sheet.pdf.

[49] MIT Technology Review, Climate Change and Energy, AI could keep us dependent on natural gas for decades to come, by David Rotman, May 20, 2025, available at: https://www.technologyreview.com/2025/05/20/1116272/ai-natural-gas-data-centers-energy-power-plants/

[50] Duke Nicholas Institute for Energy, Environment & Sustainability, Three Key Takeaways: Rethinking Load Growth in U.S. Power Systems, February 11, 2025, available at: https://nicholasinstitute.duke.edu/articles/three-key-takeaways-rethinking-load-growth-us-power-systems

[51] Duke Nicholas Institute for Energy, Environment & Sustainability, Three Key Takeaways: Rethinking Load Growth in U.S. Power Systems, February 11, 2025, p. 41, available at: https://nicholasinstitute.duke.edu/publications/rethinking-load-growth

requiring rapid response, such as frequency regulation to "dynamically adjust workloads to provide real-time support to the grid, effectively acting as 'virtual spinning reserves' that help stabilize grid frequency and integrate intermittent renewable resources."[52] TURN believes these findings and the push for more energy efficient data center operations in the sector overall support a requiring demand response program participation for Rule 30 customers.

Disappointingly, when asked about the use of the FlexConnect demand response program for Rule 30 customers, PG&E responded that "FlexConnect is only for Distribution-connected customers, and, at this time there are no distribution-interconnected data centers enrolled in the FlexConnect pilot program."[53] Further, PG&E objected to almost all of Cal Advocates data request questions about demand response participation and potential curtailments for Rule 30 customers.[54] Data centers have huge loads and research shows the potential for significant grid benefits from minor curtailments. The Commission should not allow any opportunity to mitigate potential energy price spikes, grid costs, and other potential negatives impact of Rule 30 to non-participating ratepayers go unexplored.

C. PG&E's BARC Calculation and Illustrative Bill Savings Do Not Demonstrate Benefits to Existing Ratepayers when Potential Grid Costs Are Included (Scoping Memo Issues 1, 3.e, 3.f, 3.g & 3.k)

The BARC calculation assesses the net revenue generated from non-residential line extensions. BARC calculates the incremental net system revenue generated by a new customer in order to determine how much of the customer-advanced interconnection cost a customer

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[52] Duke Nicholas Institute for Energy, Environment & Sustainability, Three Key Takeaways: Rethinking Load Growth in U.S. Power Systems, February 11, 2025, p. 12, available at: https://nicholasinstitute.duke.edu/publications/rethinking-load-growth
[53] Cal Advocates DR 11, Q 3.
[54] See PG&E Responses to Cal Advocates DR 11, Q1, Q3-8, and Q11-12.

should receive in refund. The idea is that the refunds should not exceed the amount of net incremental revenue the customer provides to the system. In this way, new large customers are ensured of *reducing* the revenue requirement that must be borne by existing customers. Intuitively, if a customer reduces the revenue requirement that other customers would have paid, existing customers are made better off all else being equal.

1. Problems with PG&E's BARC Illustrative Refund Examples

In its BARC calculation PG&E assumes interconnection costs advanced by the customer are refunded based on the Rule 30 customer reaching the projected level of demand.[55] PG&E offers two examples which demonstrate that should the customer fail to ramp-up to the projected level of electricity demand, PG&E would be kept whole for the interconnection costs since the customer refunds would be adjusted accordingly. In the actual BARC calculation, refunds would be based on the actual revenue developed from demand and usage charges.[56]

In PG&E's illustrative Example 1, the customer meets its projected electricity demand ramp up and is refunded its illustrative interconnection costs of $50 million based on the incremental net revenue provided by the customer of $83.5 million over 10 years.[57] Thus, the Example 1 customer successfully meets their forecasted demand ramp-up and provides value of $33.5 million to other customers.[58] In contrast, the Example 2 customer does not reach its forecast electricity demand ramp up and only generates incremental net revenue of $32.5 million over 10 years as compared to interconnection costs of $42.3 million, which the customer

[55] PG&E Testimony, November 21, 2024, p. 2-15.
[56] DR_TURN_002-Q001.
[57] PG&E Testimony, November 21, 2024, p. 2-15, Table 2-1 and PG&E Workpaper: ElectricRule30-Transmission-LevelInterconnections_Test_PG&E_20241121_811885.
[58] Sum of Net Revenue-Annual for years 1-10 is $83,498,519. The total refund provided to the customer is $50,000,000. Calculation: $83,498,519 -$50,000,000=$33,498,519. (Source: PG&E Workpaper: ElectricRule30-Transmission-LevelInterconnections_Test_PG&E_20241121_811885).

advanced to PG&E and $33.7 million which PG&E refunds the customer from the total advance.[59] The Example 2 customer receives a refund that is $16.3 million less than the amount advanced to PG&E for construction.

Since PG&E takes the interconnection costs into rate base as it refunds the cost of interconnect to the Rule 30 customer, the unrefunded amounts reduce associated plant and rate base.[60] Although the Example 2 customer does not receive a refund of the full advance, the refund received over 10 years is actually, *$1.2 million more than the incremental revenues* that Example 2 customer provides to PG&E's transmission revenue requirements.[61] In Example 2, although PG&E is made whole, its ratepayers are not. Accordingly, PG&E's proposed BARC formula should be rejected or the Commission must take other actions to modify Rule 30 to eliminate the potential for cost shifts from Rule 30 customers to non-participants. TURN's proposal is discussed in detail in Section IV.

2. Problems with PG&E's Illustrative Residential Customer Bill Savings

In its illustrative residential customer bill savings provided in Supplemental Testimony, for both transmission-level Customer A and Customer B, PG&E assumes a $50 million "Advance and/or Actual Cost Payments for Facility Types 1-3" and assumes $50 million for the transmission network upgrades (Facility Type 4) capital costs, resulting in $100 million of

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[59] PG&E Testimony, November 21, 2024, p. 2-16, Table 2-2. Sum of Net Revenue-Annual for years 1-10 is $32,463,006. The total refund provided to the customer is $33,678,391. Calculation: $32,463,006-$33,678,391=*negative $1,215,385*. (Source: PG&E Workpaper: ElectricRule30-Transmission-LevelInterconnections_Test_PG&E_20241121_811885).

[60] DR_CalAdvocates_004-Q003.

[61] PG&E Testimony, November 21, 2024, p. 2-16, Table 2-2. Sum of Net Revenue-Annual for years 1-10 is $32,463,006. The total refund provided to the customer is $33,678,391. Calculation: $32,463,006-$33,678,391=*negative $1,215,385*. (Source: PG&E Workpaper: ElectricRule30-Transmission-LevelInterconnections_Test_PG&E_20241121_811885).

additional rate base for a 75 MW data center project.[62] Given the huge aggregate loads clustered together and adjacent to Santa Clara County, PG&E's estimate of $50 million for Facility Type 4 capital costs may be unreasonably low. In prior investor communications PG&E has given estimates capital costs associated with data centers as a range from $500 million to $1.6 billion per GW.[63] Using the high range of PG&E's estimated per GW transmission capital costs, $1.6 billion per GW, would result in $120 million of Facility Type 4 costs for the 75 MW data center illustration—not the $50 million cost PG&E uses in its illustrative bill savings calculation.

There are several other problems with PG&E's illustrative contribution to margin calculations. First, in calculating the revenue requirement associated with the incremental capital, PG&E uses an equity ratio of 49.5%[64] when its authorized equity ratio is 52%.[65] Second, PG&E assumes 4.49% as its cost of long-term debt when in fact its current projected long-term debt rate is 5.05%.[66] Third. overall PG&E applies a return on rate base (ROR) 7.59% when it has requested a weighted average cost of capital/ROR of 8.31%.[67]

Using PG&E's own workpapers,[68] adjusting the assumed Facility Type 4 capital investment amount and the other unrealistic structure assumptions used in PG&E's examples reduces the total 10-year bill savings for residential customers from transmission-level Customer A from $27.42 total to about $16.00 over the same period 10-year period. The bill savings generated from transmission-level Customer B's additional load are reduced from $4.71 a

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[62] PG&E Supplemental Testimony, p. 30.
[63] 2024 Investor Update: Delivering For Customers and Investors." PG&E, June 12, 2024, p. 23. https://s1.q4cdn.com/880135780/files/doc_presentations/2024/June/2024-Investor-Update-Presentation_Final.pdf.
[64] Rule 30 Supplemental Testimony Work Paper 2.
[65] PG&E 2026 Cost of Capital Application (A.25-03-010), p. 1.
[66] PG&E 2026 Cost of Capital Application (A.25-03-010), p. 1.
[67] PG&E 2026 Cost of Capital Application (A.25-03-010), p. 1.
[68] Rule 30 Supplemental Testimony Work Paper 2.

negative $6.49 over the same period. Indicating that the cost of serving the additional load from hypothetical transmission-level Customer B would result in **a bill increase** over 10 years for residential ratepayers as a result of the Rule 30 proposal.

The transmission grid is designed as a mesh network in order to support reliability system stability, and interconnection with the distribution grid, so new transmission level delivery can have broader cost impacts. For example, PG&E acknowledges that large transmission customers' interconnection could create costs on the distribution network[69] which would further inflate the cost impacts of Rule 30. Finally, PG&E's analysis has not monetized any impact data centers might have on the cost of generation for other customers. In other electricity markets, large influx of data center demand has created generation capacity price spikes and significant bill increases. Based on the experience in other states, the Commission should consider any potential bill savings for customers related to new data center load doubtful.

D. Data Centers Position as a Novel Financing Source Could Put the Interest of Existing Customers at a Disadvantage (Scoping Memo Issues 3.f, 3.j & 3.k)

PG&E explains that for Transmission Network upgrade costs, "Electric Rule 30 provides an option for a customer to make a loan to PG&E that would be used to pre-fund these upgrades to accelerate work."[70] "The pre-funding loan amounts would be refunded, without interest, to the customer when the Transmission Network Upgrades are in operation.[71]

[69] DR_CalAdvocates_004-Q005.
[70] PG&E Testimony, p. 2-12.
[71] PG&E Testimony, p. 2-12.

PG&E's projected capital spending since emerging from bankruptcy has increased from roughly $8 billion annually in 2020[72] to $12 billion in 2024.[73] As California moves to address grid resiliency, climate change challenges and electrification goals, it seems likely the record of capital spending increases will continue. Any transmission upgrades or new generation to serve Rule 30 customers will only serve to exacerbate this trend.

Since 2020 PG&E has filed a succession of proposals designed to raise investment capital in non-traditional financings. This included selling its corporate headquarters in San Francisco (D.21-08-027), monetizing future tax benefits using a "rate-neutral securitization transaction" (D.21-04-030), selling a minority interest in its non-nuclear generating assets (A.22-09-018), leasing out the revenues from its transmission lines (A.24-03-009) as well as numerous requests for interim rate recovery (A.20-09-019, A.22-12-009 and Supplemental Testimony, A.23-12-001), at least one of which were granted in consideration of PG&E's capital needs (see D.23-06-004).

In its 2022 Wildfire Mitigation, Catastrophic Events (WMCE) application (A.22-12-009), PG&E requested and obtained interim rate relief stating "that financial pressure is on the utility due to both the significant undercollections in these and other balancing and memorandum accounts, and the need to finance expenses and capital expenditures not included in current rates."[74] PG&E has also asserted capital constraints in support of its proposal to sell its non-

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[72] PG&E Corporation 2020 Full Year and Fourth Quarter Earnings Presentation, February 25, 2021, slide 12, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2020/q4/EC-Q4-2020-Earnings-Presentation-Feb-25.pdf.

[73] PG&E Corporation 2024 Investor Update, June 2024, slide 11, available at: https://s1.q4cdn.com/880135780/files/doc_presentations/2024/June/2024-Investor-Update-Presentation_Final.pdf.

[74] D.23-06-004, p.11.

nuclear generating assets,[75] its petition to modify the terms of its contributions to repay the $7.5 billion securitization with which it refinanced shareholder wildfire debt, [76] [77] and most recently in the resubmission of its application to lease transmission lines to Citizen's Power.[78]

Data center developers are currently well capitalized either from the proceeds of their businesses (Google, Meta, Amazon, Microsoft) or from hedge fund and private equity investors. For example, as noted in a recent New York Times article,

> "Blackstone is already one of the world's largest owners of office buildings, warehouses and science labs, but it has sunk more money into data centers and related infrastructure than into almost any other sector in the firm's 40-year history. All told, Blackstone has put more than $100 billion into buying and lending to data centers, as well investing in construction firms, natural gas power plants and the machinery needed to build them."[79]

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[75] In its PacGen Asset Sale Application (A.22-09-018), PG&E explains it has pursued all available options to raise capital including sale of its San Francisco corporate office (D.21-08-027). PG&E states: "After pursuing all of these strategies to support PG&E's emergence and post-emergence recovery, the remaining options available to PG&E to raise new equity to fund its capital expenditure program have narrowed. PG&E Corporation's debt burden affects its credit metrics, and paying down holding company debt is an important element of the overall delevering plans for the enterprise and for returning to investment-grade issuer credit ratings." (A.22-09-018, p. 1-3.).

[76] In PG&E's petition to modify D. 21-04-030 under which it was permitted to securitize debt associated with shareholder wildfire bankruptcy liabilities (A.20-04-023), PG&E says essentially that it has insufficient funds or financial flexibility to meet both its 2024 capital expenditures and its obligations to pay ratepayers back. PG&E states: "If the Commission approves the Pacific Generation transaction, PG&E anticipates being able to make the remaining contribution to the CCT promptly following the closing of that transaction, without needing to reduce its planned spending. On the other hand, if the Commission denies the application (or imposes conditions that prevent the transaction from being consummated), PG&E will need to then take steps to plan, and subsequently execute, capital spending reductions in order to free up the cash to contribute to the CCT." (A.20-04-023, Petition of Pacific Gas and Electric Company for Modification of Ordering Paragraph 3 of Decision 21-04-030, pp. 4-5.)

[77] A proposed decision in A.20-04-023 granting PG&E's request was issued in June 2025 but is pending Commission for a vote.

[78] "PG&E has recently issued equity and worked to secure funding from the U.S. Department of Energy to finance infrastructure investment. However, these financing transactions alone are not sufficient to meet all of PG&E's infrastructure investment needs." (PG&E Amended Section 851 Application (A.24-03-009), dated January 31, 2025, p. 23).

[79] The New York Times, Wall St. Is All In on A.I. Data Centers. But Are They the Next Bubble?, Maureen Farrell, June 2, 2025, available at: https://www.nytimes.com/2025/06/02/business/ai-data-centers-private-equity.html.

Due to the rapid expansion of AI and data services, data center developers cite speed to market and speed of start up as significant success factors as competitor seek to secure clients, position, and market share in their segments.[80] PG&E's pre-funding provision would make new data centers both its customers and its bankers. Given PG&E's continual funding needs and on-going capital constraints, such a relationship represents risks for non-participating ratepayers.

At the heart of PG&E's proposal is the idea that a zero-interest loan from a customer would accelerate the customers transmission upgrade over other projects that might benefit smaller nonparticipating customers or many residential customers. As such the most important upgrade for the grid overall may not get built. In another game where shareholders win and ratepayers pay more, accelerating transmission upgrades propels the growth of PG&E's rate base (a primary driver of affordability challenges for current customers) faster and higher. This is an issue of moral hazard. PG&E has stated to its investors that each $100 million of incremental rate base represents $5 million of earnings.[81] The Commission should take extra care to ensure that Rule 30 customers in their capacity as a source of capital for PG&E are not interconnected under terms that disadvantage non-participating ratepayers.

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[80] McKinsey states: "Hyperscalers and enterprises are racing to build proprietary AI capacity to gain competitive advantage, which is fueling the construction of more and more data centers. These "builders" (as further described below) hope to gain competitive advantage by achieving scale, optimizing across data center tech stacks, and ultimately driving down the cost of compute." (Source: The cost of compute: A $7 trillion race to scale data centers, April 2025, available at: https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-cost-of-compute-a-7-trillion-dollar-race-to-scale-data-centers

[81] PG&E Corporation 2021, Fourth Quarter and Full Year Earnings Presentation, February 10, 2022, slide 48, Available at: https://s1.q4cdn.com/880135780/files/doc_financials/2021/q4/Q4'21-Earnings-Presentation_Final.pdf.

E. Rule 30 Could Negatively Impact California's Climate Goals and Electrification Strategy (Scoping Memo Issues 1 & 2)

A key driver for both data center business models and California's climate goals is the availability of renewable electricity. The New York Times reports:

> The complexity and cost of running A.I.-focused data centers stem from the vast amounts of power they guzzle, which can be about 10 to 20 times as much per server or rack as general cloud computing. There is also the need to keep the centers operational 99.999 percent of the day, or the "five nines" in industry parlance. That equates to about five minutes of downtime all year for maintenance or to switch out servers.[82]

However, California's building and transportation electrification mandates and strategies rely on the availability of those same renewable resources to facilitate low-cost charging and time of use fuel switching. All the major California IOUs are projecting significant EV load growth. Over the next four years PG&E is projecting significant load growth, in part due to residential and commercial EV adoption.[83] This growth is partially supported within existing generation and grid resources, in part by load shifting and midday charging, when there is the potential for overcapacity from renewables and grid system usage is not at peak.

EV and fuel switching not only support California's climate change mitigation goals, but can also result in savings for individual customers. The risk of Rule 30 customers out competing households and small businesses for electricity is not unforeseeable and has played out in other areas.

A jarring example of fallout on consumers is playing out on the Mid-Atlantic regional power grid, called PJM Interconnection, which serves 13 states and D.C. The recent auction to secure power for the grid during periods of extreme weather and high demand resulted in an 800

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[82] The New York Times, Wall St. Is All In on A.I. Data Centers. But Are The Next Bubble, Maureen Farrell, June 2, 2025.
[83] PG&E 2027 GRC (A.25-05-009) Exhibit PG&E-4, Vol. 1, p. 9-6.

percent jump in the price that the grid's member utilities had to pay. The impact will be felt by millions by the spring, according to public records. Power bills will increase as much as 20 percent for customers of a dozen utilities in Maryland, Ohio, Pennsylvania, New Jersey and West Virginia, regulatory filings show. That includes households in the Baltimore area, where annual bills will increase an average of $192, said Maryland People's Counsel David Lapp, a state appointee who monitors utilities.[84]

If California's relatively small margin[85] of over capacity is consumed by new data centers it will need to be replaced by new generation resources or it will prevent the retirement of existing diesel and gas resources which typically run at night. California's climate goals seek GHG reductions of 40% from 1990 levels by 2030 or a reduction of 20 million tons of CO_2.[86] However, the addition of 3.5 GW of new data center load operating nearly 24 hours a day would demand kilowatt hours at night when California relies on fossil resources and nuclear power. TURN estimates that the GHG emissions associated with the incremental data center load of roughly 1.5 million tons,[87] a step in the wrong direction. Although the Commission decided the impacts to disadvantaged communities and equity implications from the greater reliance on natural gas generation needed to serve Rule 30 customers is not in scope for this proceeding, it is valuable to note that natural gas generation is typically located in the poorest neighborhoods, adding potential co-morbidities to the on-going affordability challenges already faced by low-

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[84] Washington Post, "As data center for AI strain the power grid, bills rise for everyday customers," Evan Halper and Caroline O'Donovan, November 1. 2024, available at: https://www.washingtonpost.com/business/2024/11/01/ai-data-centers-electricity-bills-google-amazon/

[85] TURN estimate that the number of hours in CAISO in 2024 with zero or negative prices was 6.8% of hours. (source: https://emp.lbl.gov/publications/exploring-wholesale-energy-price).

[86] California Releases World's First Plan to Achieve Net Zero Carbon Pollution, available at: https://www.gov.ca.gov/2022/11/16/california-releases-worlds-first-plan-to-achieve-net-zero-carbon-pollution/

[87] TURN assumes 40% of hours are natural gas-fired generation, 100% load factor, 7500 BTU per kWh, and CO_2 emissions of 53 kg per MMBTU.

income Californians. Further, the Commission should not ignore the fact that the huge need for nearly continuous energy by data centers raises issues for California's climate change goals.

PG&E states that the two transmission-voltage connected data centers in PG&E's service territory have diesel generators as back up.[88] Because of the inexpensiveness of diesel generators relative to renewable or battery storage capacity, absent specific requirements, TURN believes that data center customers will opt to use diesel generation as backup, favoring speed of implementation unless Rule 30 is modified to require sustainable back up. As discussed in Section III.B above, the combination of storage with required demand response could help support climate change goals and mitigate data center near-term energy price impacts on non-participating customers.

IV. PG&E'S PROPOSED RULE 30 MUST BE MODIFIED TO PROTECT EXISTING RATEPAYERS FROM POTENTIAL COSTS AND HARMS (SCOPING MEMO ISSUES 1 & 3)

Given the potential for cost shifts from Rule 30 customers to non-participants TURN does not recommend any departure from the exceptional case filing process that PG&E currently uses to connect large loads. Most notably, PG&E has not advanced an appropriate large customer tariff or rate structure in conjunction with its proposed Rule 30 which would allow the Commission to prevent unfair cost shifts.[89] Any final transmission-level electric rule approved in this proceeding will inform applicable tariffs for other California investor-owned utilities. Rather than approving PG&E's Rule 30, the Commission should consider deferring any final decision in this proceeding until an rulemaking concerning data center interconnection issues can be opened to address statewide impacts and issues.

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[88] ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_004-Q017.

[89] A.24-09-014, Public Advocates Office Motion To Amend The Scoping Memo To Include Issues From Application 24-11-007, pp. 1-2.

As discussed above in this Testimony, proliferation of data centers raises risks for non-participants including: 1) over-refund of initial interconnection costs due to deficiencies in the BARC methodology; 2) cost shifts for expensive transmission and distribution upgrades, 3) raising generation capacity costs leading to higher bills for existing customers, 4) blackouts due to energy shortages at times of peak demand, 5) decreased time of use fuel switching capability to support climate change goals; and 6) increasing greenhouse gas emissions from fossil generation to meet higher loads at night. Absent a case-by-case exception process, likely grid impacts of an individual customer will not be evaluated before the interconnection is approved, and existing ratepayers and non-participants will simply have to live with the consequences of connecting Rule 30 customers (primarily data centers) *en mass;* and captive, current ratepayers will have to pay for those effects.

Should the Commission decide to approve Rule 30, it should require the modifications to address the following issues and help protect PG&E's existing ratepayers from harm.

A. PG&E's BARC Formula does not Protect Non-Participants from Subsidizing Rule 30 Customers by Over-Refunding Interconnection Costs (Scoping Memo Issues 3.f 3.g & 3.k)

As discussed in Section III.C, PG&E's BARC formula does not ensure that Rule 30 customers do not receive a refund of their interconnection costs that is greater than the net transmission revenues they provide on the system. Thus, non-participants are not always made whole for even just Rule 30 interconnection costs (Facility Types 1-3). Although under Rule 30 the customer may elect to construct the Transmission Service Facilities (Facility Type 1) and/or transmission interconnection upgrades (Facility Type 2) or have PG&E do so,[90] data center developers command significant potentially low-cost capital and may have access to effective

[90] A.24-11-007, PG&E Testimony, p. 1-13.

equipment supply chains. As such the cost for the customer to construct may be lower than PG&E's. TURN recommends that:

- the BARC formula used to compute the amount of refund a Rule 30 customer receives should be modified as proposed by Cal Advocates in this proceeding.
- Regardless of who constructs the interconnection facility, the costs included in rate base should be the lower of PG&E's projected construction cost, or the developer's projected construction cost.

B. PG&E's Rule 30 does not Ensure that Rule 30 Customers will Pay the Expected Level of Incremental Revenues over the 10 year Contract Term (Scoping Memo Issues 1, 3.f 3.g & 3.k)

As discussed in Section III, it is unlikely that the revenues from additional electricity sales to Rule 30 customers will result in bill savings to non-participants. TURN recommends that Rule 30 be modified to require that customers pay all projected incremental revenues over the 10-year contract. Should a Rule 30 customer depart before the completion of the contract, the customer would be subject to loss of the remaining interconnection refund, as is currently proposed, but would also be subject to payment of an exit fee equal to any remaining incremental revenues based on the original projections. This provision has been enacted in Oregon for large energy use facilities using 20 MWs of more.[91]

C. PG&E's Proposed Rule 30 Tariff does not Address the Potential for Costly Grid Upgrades Related to Data Center Interconnections (Scoping Memo Issues 1, 3.d 3.e & 3.k)

TURN supports Cal Advocate's motion in PG&E's 2025 GRC Phase 2 (A.24-09-014) to include rate structures for large load transmission-level customers in the scope of that proceeding. Further, TURN recommends:

- The Commission in this proceeding direct PG&E to file supplemental testimony in A.24-09-014, proposing: 1) one or many large customer rate schedules appropriate for

[91] Oregon House Bill 3546, signed by Governor June 16, 2025, see Section 5, available at https://olis.oregonlegislature.gov/liz/2025R1/Downloads/MeasureDocument/HB3546.

Rule 30 customers; 2) one or many demand response programs appropriate for Rule 30 customers.

- The approval of a final version of Rule 30 (if authorized in this proceeding) should be conditional upon implementation of large customer rate schedules and demand response programs in A.24-09-014.
- Interim Rule 30 customers based on the proposed decision of ALJ Lakhanpal issued June 20, 2025 in this proceeding, should be required to adopt the large customer rate schedule(s) and demand response program participation when finalized.

D. PG&E's Rule 30 Proposal does not Address Potential Near-Term Impacts of Large Loads on Generation Markets and Non-Participant Costs (Scoping Memo Issues 3.e & 3.k)

As discussed in Section III.B, adverse effects have been experienced in other states and jurisdictions due to an influx of large data center loads. TURN recommends several additions to Rule 30 participation requirements.

- Rule 30 participants should be required to enroll in a mandatory demand response program appropriate for large transmission-level customers developed or approved in A.24-09-014, or other appropriate Commission proceeding.
- In addition to providing interconnection facilities, Rule 30 Tariff customers with load factors greater than 70% should be required to include 4-hour battery storage capacity or other behind the grid clean energy capacity equal to 100% of their projected load, rather than diesel backup generation. This additional storage could provide lasting grid benefits regardless of whether large customers remain on the system over the 10-year proposed BARC recovery term.

APPENDIX A - JENNIFER DOWDELL STATEMENT OF QUALIFICATIONS

Jennifer Dowdell is a Senior Policy Expert with The Utility Reform Network (TURN). Prior to joining TURN in 2019, Ms. Dowdell specialized in financial forecasting and data analysis as an independent consultant, where she supported clients in a wide range of industries. Her professional experience includes over 40 years in regulated utilities, independent power, financial services, and accounting. Ms. Dowdell has held positions in engineering, corporate communications, investment research, merchant banking, project finance, venture capital, and accounting operations at leading corporations including Duff & Phelps Investment Research, Sanwa Bank, and Gilead Sciences.

Ms. Dowdell's specific utility experience includes four years in design engineering and environmental compliance at Exelon Corporation, four years developing independent power projects in California for Calpine Corporation, and four years as a securities analyst and a project finance lender in the energy sector. For 13 years, Ms. Dowdell worked for Pacific Gas and Electric Company in a variety of consulting and employee roles, including six years at the leadership/director-level. Her assignments included strategic planning and regulatory relations, as well as managing investor relations and payment services functions. During her tenure at PG&E, Ms. Dowdell participated in multiple GRCs and Cost of Capital cases as well as many other policy proceedings where she developed regulatory strategy, wrote and sponsored testimony, and engaged in regulatory advocacy.

Ms. Dowdell's education includes a Bachelor of Science degree in Mechanical Engineering from Purdue University, and an MBA in Economics and Finance from The University of Chicago, Booth Graduate School of Business. She has a Graduate Certificate in Accountancy from Golden Gate University and is a California-licensed Certified Public

Accountant (CPA). Ms. Dowdell is also a Chartered Financial Analyst (CFA) and has held FINRA Series 7 and Series 66 licenses. Ms. Dowdell has been a member of CalCPA since 2010, and CFA Institute since 1991.

APPENDIX B - ATTACHMENTS

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 – Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	TURN_001-Q007
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_TURN_001-Q007
Request Date:	February 5, 2025
Requester DR No.:	001
Requesting Party:	The Utility Reform Network
Requester:	Elise Torres, Reina Yanagiba, Jennifer Dowdell
Date Sent:	March 6, 2025
PG&E Witness(es):	Karen Khamou Ornelas – Engineering, Planning and Strategy

SUBJECT: PG&E RULE 30 APPLICATION & TESTIMONY

The following questions relate to PG&E's Application for Approval of Electric Rule No. 30 for Transmission-Level Retail Electric Service, filed on November 21, 2024 and its accompanying Testimony.

QUESTION 007

On pages 1-1 and 1-2 of its Testimony, PG&E states that it "has experienced a significant increase in requests from new retail electric customers with substantial electric demand which require interconnection at a transmission voltage" and that it "expects that this trend will accelerate with the rapid growth of data center construction and the addition of other new retail electric customers with substantial electric demand."

Please answer the following questions regarding these statements:

a. How many transmission level interconnection requests does PG&E expect in the next five years?

b. What percentage of expected requests does PG&E expect to come from data centers?

c. Please provide a breakdown of expected transmission interconnection requests by industry/customer type.

d. How many new data centers does PG&E expect to be constructed in its territory within the next five years?

e. Provide the expected MW demand in the next five years, broken down by customer class.

f. Provide the basis for these forecasts.

ANSWER 007

Please note that attachment to this data response contains highly confidential information and is provided pursuant to the attached declaration dated March 6, 2025.

Highly confidential Attachment *ElectricRule30-Transmission-LevelInterconnections_DR_TURN_001-Q007Atch01_CONF.xlsx* provides information responsive to Question 7(a). This attachment includes the requests for transmission voltage service we have to date. PG&E utilized multiple data sources to update this attachment. Sources can be from the applicant's application, preliminary engineering studies, and updates from our customers. This file is continuously updated to have the most up-to-date data for projects requesting transmission voltage service. **Please note that because this attachment includes confidential customer information, it has been marked as Highly Confidential Material under the terms of the Non-Disclosure Agreement between TURN and PG&E.**

a. See Tab "Q7a Active Request Pivot". As indicated in the Application and Prepared Testimony, PG&E has seen a significant increase in requests for transmission level service within the past two years. In addition, there have been substantial changes in policy at the national level that may significantly impact requests for transmission level interconnections going forward and California is considering legislation which could also significantly impact data centers and other transmission level customers. Given the limited data and significant policy changes, we are unable to predict at this time the number of transmission level interconnection requests that PG&E will receive in the next five years.

b. See subpart (a).

c. See subpart (a).

d. See Tab "Q7d Interconnection Pivot". This tab provides the anticipated interconnection year that a project will be placed in service. This response is derived from several sources, including the application's requested interconnection date, the preliminary engineering study, or real-time updates provided by the project team. The current data indicates that there are a total of 34 Data Center projects expected to achieve interconnection between the years 2025 and 2029. However, this forecast may substantially change based on federal and state policies, economic conditions, and other factors that could impact the decision to locate a data center in PG&E's service territory, including Commission action on Electric Rule 30. In addition, factors such as the scope of work, permitting processes, long lead materials, the timing of exceptional case filings, and unforeseen circumstances can all lead to alterations in the schedule. There are currently 16 of the 34 Data Center projects which completed the study phase and moved on the design phase. Advancing to the design phase helps with the certainty of the project being energized in a timely manner.

e. Utilizing tab "Q7-Q8-Q9-Q10 Active Data" with the study types and forecasted load ramps, PG&E provides the following summary:

Site Type	2025, MW	2026, MW	2027, MW	2028, MW	2029, MW	2030, MW
Data Center	21.5	313.8	709.8	3,967.4	5,159.9	5,890.2
EV	0	26.4	28.4	37.1	42.1	50.7
Government	44	44	68.8	68.8	68.8	95.8
Industrial	0	8	59	60	61	69.5
Manufacturing	30	102.8	123	150	162	190.2
University	0	10	12	67	88.8	98.8

It is important to recognize that, as stated previously in response subpart (d), evaluating the number of projects that will be energized is difficult due to the constraints of the available information known during the current phase of the project, as well as the variability in customer load on an annual basis. This data is subject to change as each project progresses through the various phases.

f. See subparts (d) and (e).

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 – Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	TURN_002-Q001
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_TURN_002-Q001
Request Date:	April 9, 2025
Requester DR No.:	002
Requesting Party:	The Utility Reform Network
Requester:	Jennifer Dowdell/ Elise Torres/ Reina Yanagiba
Date Sent:	April 21, 2025
PG&E Witness(es):	Ben Moffat – Engineering, Planning and Strategy

SUBJECT: PG&E RULE 30 APPLICATION & TESTIMONY

The following questions relate to PG&E's Application for Approval of Electric Rule No. 30 for Transmission-Level Retail Electric Service, filed on November 21, 2024 and its accompanying Testimony.

QUESTION 001

Referring to PG&E's Supplemental Testimony, pp. 51-54 and the Base Annual Revenue Calculation (BARC) process,

1. Please describe and explain how PG&E will confirm that the actual Rule 30 customer demand charges and kWh purchases are the same as PG&E's BARC forecast values? If PG&E's process does not confirm actual values are the same as forecast values, please clearly state that this is the case.
2. If PG&E's Rule 30 BARC process includes confirmation that forecasted and actual demand charges and kWh purchases are the same, please explain and describe how often this process will occur and over what period.

ANSWER 001

1. Actual Rule 30 Customer demand charges and kWh purchases are not the same as PG&E's BARC forecasted values. Rule 30 BARC reviews for refunds will be based on actual revenue developed from demand and usage charges. See PG&E Supplemental Testimony, p. 48, lines 2-8. For more detail concerning the BARC calculation, please see PG&E's Supplemental Testimony, Workpaper 1.

2. See PG&E's response to subpart (1) above.

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 - Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	CalAdvocates_004-Q003
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_004-Q003
Request Date:	February 21, 2025
Requester DR No.:	004
Requesting Party:	Public Advocates Office
Requester:	Jane Roschen
Date Sent:	March 7, 2025
PG&E Witness(es):	Kevin Chang – Finance

SUBJECT: EXISTING PROCESS

QUESTION 003

At a high level, what is the contribution of customer connection costs (Electric Rule 15 and 16) to PG&E's total weighted average rate base? In other words, how much of PG&E's total Plant is attributable and/or related to new customer-specific and non-coincident demands (e.g., service drops, line transformers) on the local distribution system?

a. In Electric Rule 15, Section D.5.c describes the non-refundable discount option available to customers for distribution line extensions. Describe how PG&E uses the unrefunded portion of the customer's advance and/or contribution in ratemaking. Does PG&E reduce Plant by the non-refundable portions, similar to the approach proposed in Electric Rule 30?

ANSWER 003

PG&E objects to this request as outside the scope of this proceeding because this proceeding concerns Electric Rule 30 and transmission level interconnections. Subject to and without waiving this objection, PG&E does not track the total plant over time related to the customer connection costs.

a. Yes. The non-refundable portion of customer advances amounts are used to reduce plant.

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 - Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	CalAdvocates_004-Q005
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_004-Q005
Request Date:	February 21, 2025
Requester DR No.:	004
Requesting Party:	Public Advocates Office
Requester:	Jane Roschen
Date Sent:	March 20, 2025
PG&E Witness(es):	Ashwini Mani – Electric Engineering

SUBJECT: EXISTING PROCESS

QUESTION 005

What is the average cost to interconnect a customer onto PG&E's transmission system? Use historical data and specify which historical range this average cost is derived from.

a. Please provide the following average cost per unit estimates using data from the 16 customers which interconnected at transmission-level voltages between 2014 to 2022[1] onto PG&E's electrical system:

   i. Service upgrades at transmission voltages (Facility Type 1) on a $/MW basis.

   ii. Transmission interconnection upgrades on a $/MW basis (Facility Types 2 and 3).

   iii. Network Upgrade to the CAISO system on a $/MW basis (Facility Type 4).

   iv. Describe the consistency of the $/MW cost across the 16 customer interconnection projects and the main factors that led to variation in the $/MW cost.

   v. If available, compare these estimates with costs derived from the 2024 Large Load Preliminary Engineering Cluster Study.

b. Provide actual costs from facilities installed to connect new transmission-level customers and designed as "Special Facilities" by PG&E for the 16 customers described in 5.a.

c. List the types of distribution equipment commonly needed to connect a non-residential electric customer onto PG&E's system at distribution voltages and the

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[1] Application (A.) 24-11-007, *Application of Pacific Gas and Electric Company (U 39 E) for Approval of Electric Rule No. 30 for Transmission-Level Retail Electric Service,* November 21, 2024 (Application) at 5.

average cost for each piece of equipment. Use historical data and specify which historical range this average cost is derived from.

i. Describe possible circumstances in which new transmission-level loads would trigger an upgrade to PG&E's distribution system to maintain grid operations and reliability.

ANSWER 005

a. PG&E notes that, prior to Electric Rule 30, it did not categorize facilities as Facility Types 1-4. In addition, PG&E objects to this request as overbroad and burdensome as it would require PG&E to go back through eight years of project specific information and to try to separate into Facility Types the actual costs for project specific work. PG&E further objects because information regarding costs in 2014, example, will be dated given significant national and international inflationary trends, increases in commodity and equipment prices, and the potential for future tariffs or other federal or state actions that may significantly impact prices and thus is not relevant in this proceeding. Subject to and without waiving these objections and clarifications, PG&E Per Unit costs are available on the California Independent System Operator (CAISO) website. The spreadsheet has itemized costs for the typical Upgrades the PG&E identifies as part of interconnection studies. https://www.caiso.com/library/participating-transmission-owner-per-unit-costs

b. PG&E objects to this request as overbroad and burdensome as it would require PG&E to go back through eight years of project specific information and to try to identify the costs of Special Facilities, if any. PG&E further objects because information regarding costs in 2014, example, will be dated given significant national and international inflationary trends, increases in commodity and equipment prices, and the potential for future tariffs or other federal or state actions that may significantly impact prices and thus is not relevant in this proceeding. Subject to and without waiving these objections, please see PG&E's response to subpart (a).

c. Please note that the following list only includes distribution upgrades at primary voltages. The distribution system is the portion of the electric system composed of distribution substation and primary line equipment that run at voltages from 4,000 volts to 34,500 volts. Customer-driven expansion of the distribution system would include some of the costs below. Any upgrades would be highly variable and dependent on customer load, customer location, and existing distribution asset capacity. The list below does not include costs for expansion of the secondary system. The secondary system is the low-voltage system comprised of voltages between 120 and 480 volts that directly serve homes and businesses. The list below also does not include costs such as metering. The following data was included in the 2023 General rate Case (GRC) and will be updated in the 2027 GRC filing.

Workpaper Table 17-27
Pacific Gas and Electric Company
Exhibit (PG&E-4), Chapter 17, Electric Distribution Capacity, Engineering, and Planning

Unit Cost and Forecast Details by Asset Type

Line No.	Description	Unit Cost	Per
1	New Substation Total	$27,000,000	Substation
2	Construction	$18,600,000	Substation
3	Regulatory	$6,000,000	Substation
4	Land	$2,400,000	5 Acre Parcel
5			
6	Substation Transformers	$11,800,000	Transformer, = < 45 MVA with Switchgear
7		$8,400,000	Transformer, = < 45 MVA Outdoor Bus, Install
8		$6,500,000	Transformer, = < 45 MVA Outdoor Bus, Replace
9			
10	Circuit Switcher or Breaker	$2,200,000	High Side Circuit Switcher or Circuit Breaker
11	Breakers	$1,400,000	Low Side Circuit Breaker
12	Recable SF Circuit outlet in indoor substations	$1,100	Foot
13			
14	Non-Bay		
15	OH New	$160	Foot
16	OH Reconductor	$160	Foot
17			
18	OH Capacitor (Cap)	$33,000	Capacitor
19	OH Switch	$30,000	Switch
20	OH SCADA Switch	$45,000	Switch
21	OH Regulator	$150,000	3 Regulator Bank
22	OH Recloser	$80,000	Recloser
23	OH Fuse/Disconnect	$10,000	Fuse/Disconnect
24	OH SCADA, no equipment replacement	$15,000	Location
25	Reclocate Capacitor	$18,000	Capacitor
26			
27	UG New w/trench	$320	Foot
28	UG New no trench	$260	Foot
29			
30	Service transformer replace	$34,000	Service Transformer Replacement (blended overhead and underground)
31	Autotransformer	$850,000	Autotransformer
32	UG Switch	$80,000	Switch
33	UG SCADA Switch	$130,000	Switch
34	UG Interrupter	$120,000	Interrupter
35	PM Capacitor	$65,000	Capacitor
36			
37	Bay		
38	OH New	$220	Foot
39	OH Reconductor	$220	Foot

Line No.	Description		Unit Cost		Per
40	OH New - SF Only		$500		Foot
41	OH Reconductor - SF Only		$500		Foot
42					
43	OH Capacitor (Cap)		$33,000		Capacitor
44	OH Switch		$30,000		Switch
45	OH SCADA Switch		$45,000		Switch
46	OH Regulator		$150,000		3 Regulator Bank
47	OH Recloser		$80,000		Recloser
48	OH Fuse/Disconnect		$10,000		Fuse/Disconnect
49	OH SCADA, no equipment replacement		$15,000		Location
50	Relocate Capacitor		$18,000		Capacitor
51					
52	UG New w/trench		$410		Foot
53	UG New w/trench - SF Only		$780		Foot
54	UG New no trench		$315		Foot
55	UG New no trench - SF Only		$600		Foot
56					
57	Service transformer replace		$34,000		Service Transformer Replacement (blended overhead and underground)
58	Autotransformer		$850,000		Autotransformer
59	UG Switch		$80,000		Switch
60	UG SCADA Switch		$130,000		Switch
61	UG Interrupter		$120,000		Interrupter
62	PM Capacitor		$65,000		Capacitor

(1) All regulators are purchased in MAT 06#, therefore unit costs identified here exclude the cost of material.

(2) Unit Costs are an average of recorded costs of similar work.

The only instance where new transmission-level loads would trigger an upgrade to PG&E's distribution system would be where new transmission-level loads cause the conversion of the transmission system from one transmission voltage to a higher transmission voltage. In that instance, any distribution substation transformers that are not capable of being served by the higher transmission voltage would require replacement with new substation transformers that can interconnect at the higher voltage.

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 - Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	CalAdvocates_004-Q008
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_004-Q008
Request Date:	February 21, 2025
Requester DR No.:	004
Requesting Party:	Public Advocates Office
Requester:	Jane Roschen
Date Sent:	February 3, 2025
PG&E Witness(es):	Ben Moffat – Engineering, Planning and Strategy

SUBJECT: ELECTRIC RULE 30 PROPOSAL

QUESTION 008

PG&E states in its January 2, 2025 Reply to Protests and Responses Regarding Proposed Electric Rule 30 , "Southern California Edison Company (SCE) and San Diego Gas & Electric Company (SDG&E) may have very different transmission-level customer needs and designs of their respective electrical grids such that proposed Electric Rule 30 should not be generalized to all three utilities."[1] Describe PG&E's understanding of the different needs in SDG&E and SCE territories compared with PG&E's territory and how the generalized nature of Rule 30 to address all transmission-level customers is not inclusive of customer needs in other areas of California.

ANSWER 008

PG&E has not done a thorough analysis of differences between SCE's and SDG&E's potential transmission level customers and the designs of their respective electrical grid and PG&E's potential transmission level customers and the design of its electrical grid. This is why PG&E stated that there "may" be differences between PG&E and SCE/SDG&E. However, in proceedings before FERC regarding the creation of the CAISO, the CPUC has noted that there are "historical facts relating to the unique design of each utility's integrated transmission system." *See Pacific Gas and Electric Company*, 77 FERC ¶ 61,077 (1996). In addition, in other proceedings, the CPUC has allowed for variations between the utilities recognizing "differences in their underlying distribution and transmission systems." *See* D.13-05-034 at 66. These decisions indicate that the CPUC has recognized that differences exist between the PG&E, SCE, and SDG&E transmission systems.

[1] A.24-11-007, Pacific Gas and Electric Company (U 39 E)'s Reply to the Protests and Responses Regarding Proposed Electric Rule 30, January 2, 2025, at 5.

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 - Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	CalAdvocates_004-Q012
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_004-Q012
Request Date:	February 21, 2025
Requester DR No.:	004
Requesting Party:	Public Advocates Office
Requester:	Jane Roschen
Date Sent:	March 12, 2025
PG&E Witness(es):	Ashwini Mani – Electric Engineering

SUBJECT: ELECTRIC RULE 30 PROPOSAL

QUESTION 012

In response to Data Request No. Cal Advocates 02_Q002, PG&E explained that it may designate certain facilities required for interconnection as Special Facilities when "PG&E believes [the estimated load] is not bona-fide." Provide PG&E's definition of "bona-fide" as used in the case of proposed Rule 30.

a. Further, Rule 30 Section A.3.a explains that "bona-fide load is determined by PG&E using actual and historic load(s) for customer(s) of similar type and size."

Describe the process through an example in which PG&E would determine a customer's load is "non bona-fide" and any standardized metrics PG&E has used in the past to determine the reasonableness of load interconnection requests.

ANSWER 012

PG&E has three methods for estimating non-residential demand and bona-fide load. These are:

- Method 1 (Preferred): Historical demand of similar customers
- Method 2: Demand per square foot by type of occupancy
- Method 3: Customer plans and operational needs

Although historical demand from specific customers is the main way that bona-fide load is established, those numbers are not provided here due to customer confidentiality concerns.

Some examples of typical watts per square foot are as follows:

Occupancy Type	Historical Range of Maximum Volt Amperes per Square Foot
Colleges	4.5 - 6.1
Hospitals	5.5 – 7.7
Offices	4.0- 5.0
Shopping Centers	4.5 - 6.1
Greenhouse Cultivation	14.0
Indoor Cultivation	46.0
Data Centers	75.0-100.0

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 - Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	CalAdvocates_004-Q017
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_004-Q017
Request Date:	February 21, 2025
Requester DR No.:	004
Requesting Party:	Public Advocates Office
Requester:	Jane Roschen
Date Sent:	March 12, 2025
PG&E Witness(es):	Art McAuley – Engineering, Planning and Strategy

SUBJECT: DATA CENTERS AND PG&E SYSTEM LOADS

QUESTION 017

How many data centers with demands over 1 MW in PG&E's service territory currently use backup generation on-site and from what source (e.g., diesel, Solar PV, Engine, Battery Energy Storage)? How many of these systems are grid-connected?

a. In the "TD-9101P-01, Attachment 3 Large Load Interconnection Procedure, 03/2022" form, PG&E asks for estimates of a customer's "onsite generation" and "backup generation". Please provide definitions for these terms.

b. What regulation is in place for the technical operation of and switching to and from on-site generation? Is there a limit how often or how much on-site energy can be used?

ANSWER 017

There are only 2 transmission-voltage connected data centers currently operational in PG&E's service territory. Both data centers have non-export back-up generating units with # 2 diesel as the fuel source for these back-up generating units. Of the approximately 76 distribution-interconnected data centers, PG&E does not have information concerning how many have on-site backup generation.

a. In the "TD-9101P-01, Attachment 3 Large Load Interconnection Procedure, 03/2022" form, PG&E asks for estimates of a customer's "onsite generation" and "backup generation." Onsite generation is behind-the-meter generation typically paralleled with the utility grid to provide all or a portion of a customer's energy requirements, perform peak load shaving, etc. Backup generation is a subset of onsite generation in that the generator is employed only when there is an electric outage to the customer's utility provided electric service. Energy produced from back-up generating units never registers in the utility meters and backup generation can be: (1) closed transition with a direct transfer trip (DTT) scheme or what is referred to as Make-Before-Break which momentarily parallels the grid, or (2) open transition or what is referred to as Break-Before-Make, where the Customer will experience an outage and a delay before the generator is connected and supplying power typically to critical loads.

b. On-site generation operation is predicated solely at the discretion of the customer. On-site generation is required to comply with CPUC-approved Electric Rule 21 requirements, either the PG&E Transmission Interconnection Handbook or PG&E Distribution Interconnection Handbook, and requirements and regulations of the California Air Resources Board, along with any from the local jurisdiction. A Generation Interconnection Facility Agreement (GFIA) Form 79-973 or 79-1070 may also be required.

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 - Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	CalAdvocates_004-Q018
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_004-Q018
Request Date:	February 21, 2025
Requester DR No.:	004
Requesting Party:	Public Advocates Office
Requester:	Jane Roschen
Date Sent:	March 21, 2025
PG&E Witness(es):	Ben Moffat – Engineering, Planning and Strategy

SUBJECT: DATA CENTERS AND PG&E SYSTEM LOADS

QUESTION 018

Provide the aggregated annual energy consumption (GWh) of new retail electric service customers in a hypothetical future year in which all 59 applications currently requesting transmission-level service are successfully interconnected to PG&E's system and have fully materialized loads. If an aggregated annual energy consumption metric is not available, please use the monthly load profiles provided to PG&E in the "TD-9101P-01, Attachment 3 Large Load Interconnection Procedure, 03/2022" as a metric to convert power (MW) to energy (GWh).

ANSWER 018

In its Supplemental Testimony, PG&E has indicated that "[s]ince 2023, PG&E has received 40 active applications for transmission level service with demand of 4 MW or greater." PG&E understands that this data request is seeking annual energy consumption forecasted for these 40 applications assuming: (1) the forecasts provided by the applicants are accurate; and (2) all of the facilities proposed are actually constructed. Subject to this clarification, the aggregated annual energy consumption (GWh) is listed at the table below. The most recent data of load profiles was utilized for this calculation.

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
MW	30	299	1,225	3,451	5,183	6,489	7,764	7,974	8,236	8,368	8,396	8,396	8,422	8,422	8,422	8,422	8,173
GWh	210	2,095	8,586	24,185	36,325	45,474	54,410	55,878	57,717	58,641	58,837	58,837	59,019	59,019	59,019	59,019	57,278

PACIFIC GAS AND ELECTRIC COMPANY
Electric Rule 30 - Transmission-Level Interconnections
Application 24-11-007
Data Response

PG&E Data Request No.:	CalAdvocates_011-Q003
PG&E File Name:	ElectricRule30-Transmission-LevelInterconnections_DR_CalAdvocates_011-Q003
Request Date:	May 30, 2025
Requester DR No.:	011
Requesting Party:	Public Advocates Office
Requester:	Jane Roschen, Emil Rodriguez, David Peck, Sanya Kwatra
Date Sent:	June 5, 2025
PG&E Witness(es):	

QUESTION 003

What existing Demand Response programs are applicable or not applicable for Proposed Rule 30 customers and why? Are there any restrictions on Proposed Rule 30 customers participating in Demand Response programs (i.e., Peak Day Pricing, Base Interruptible Program, Capacity Bidding Program, Emergency Load Reduction Program, Automated Demand Response Program)?

ANSWER 003

Please see PG&E's objection to Question 1.

Wall St. Is All In on A.I. Data Centers. But Are They the Next Bubble?

Private equity firms like Blackstone are using their clients' money to buy and build data centers to fuel the artificial intelligence boom.

Listen to this article · 10:16 min Learn more

By Maureen Farrell

Maureen Farrell traveled to Northern Virginia and talked to dozens of data-center executives, employees and investors in the United States and abroad to report this article.

June 2, 2025

Artificial intelligence still seemed the stuff of science fiction when a real estate developer named Chad Williams bought a plot of land, roughly half the size of a football field, in Overland Park, Kan.

Mr. Williams, who had taken over his family's business of car lots and office furniture suppliers, used the land in 2003 to build his first data center, a big, boxy warehouse housing powerful computers.

More than two decades later, the company Mr. Williams built, Quality Technology Services, is at the heart of one of Wall Street's biggest gambits: the race to profit from artificial intelligence.

The private equity giant Blackstone spent $10 billion in 2021 to acquire QTS, and has been pouring billions more into the company to help it expand its data centers. These giant buildings house the backbone of the internet — and more recently artificial intelligence systems — using technology and heating and cooling systems to keep the computers inside the centers humming.

This largely unglamorous industry is critical for A.I. leaders to get right. QTS leases its facilities to companies like Amazon and Meta and supplies the electricity and water needed to power and cool their computers.

QTS tenants include major technology companies that are opening up their wallets on A.I. investments. Greg Kahn for The New York Times

Blackstone calls data centers one of its “highest conviction investments.”

Blackstone is already one of the world’s largest owners of office buildings, warehouses and science labs, but it has sunk more money into data centers and related infrastructure than into almost any other sector in the firm’s 40-year history. All told, Blackstone has put more than $100 billion into buying and lending to data centers, as well investing in construction firms, natural gas power plants and the machinery needed to build them.

Blackstone is not alone. Data centers are drawing a crowd on Wall Street — investment giants like KKR, BlackRock and Blue Owl have collectively plowed hundreds of billions into the industry. As investment firms announce larger and larger deals, one Wall Street executive says he jokes about “Braggawatt” deals, as data centers are typically measured by the wattage they use.

The spending frenzy has created concerns about whether too many data centers are being built. A TD Cowen analyst, Michael Elias, warned of potential “oversupply” in the market as some technology companies, including Microsoft and Foxconn, have stepped away from some leases. Still, there has been a flurry of announcements in just the last two weeks: OpenAI plans to build a massive computing complex in the United Arab Emirates, and the investor Chamath Palihapitiya said he had bought real estate in Arizona and planned to ultimately raise $25 billion to build a data center there.

The chairman of Alibaba, Joe Tsai, said he was starting to see “the beginning of some kind of bubble” in data center construction. John Lamparski/Agence France-Presse — Getty Images

Joe Tsai, chairman of Alibaba, which views A.I. as core to its business, also said he was starting “to see the beginning of some kind of bubble” in data center construction.

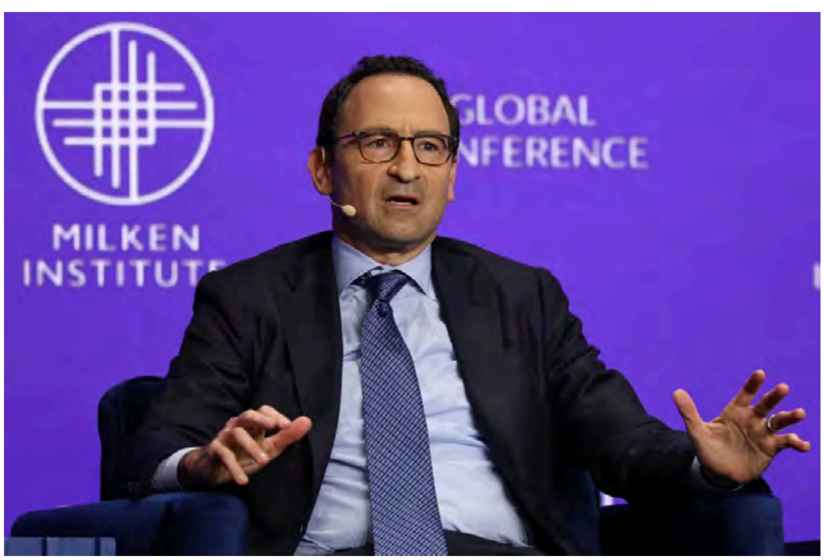
Blackstone, on the other hand, says it still sees strong demand from tech companies, which are willing to sign what they describe as airtight leases for 15 to 20 years to rent out data center space.

“It’s not like building condos in Miami,” the company’s president, Jonathan Gray, said in a Bloomberg interview in January, noting that Blackstone starts building only once it has a locked-in tenant.

And even as questions about overbuilding have surfaced, Blackstone has reiterated its commitment to building more centers and investing in the power plants needed to run the computers inside them.

Well-timed real estate bets are what have vaulted Blackstone past its rivals to make it the world’s largest private equity firm.

Mr. Gray was the chief architect of the firm’s race to buy foreclosed homes in the wake of the financial crisis. Blackstone became the largest owner of single-family homes in the United States for many years. It sold those homes for a profit of more than $7 billion.



Blackstone's president, Jonathan Gray, said Blackstone started building only once it had a locked-in tenant. Patrick T. Fallon/Agence France-Presse — Getty Images

The timing of Blackstone's acquisition of QTS also looks fortuitous.

QTS went public in 2013, but its stock price languished, largely because it constantly needed more money for new data centers that would take years to build. Since banks would lend the company only so much, QTS had to raise more money from stock market investors, making existing shares less valuable.

"Public markets don't like it when you buy land and then we tell you, 'I'm not going to have a return on this for four years,'" said Tag Greason, co-chief executive of QTS.

In the summer of 2021, when Blackstone purchased QTS, the release of ChatGPT was still about a year away. The QTS acquisition barely warranted a mention during the private equity firm's quarterly conference calls.

When ChatGPT was released in 2022, it created a buying frenzy in A.I. companies like Nvidia, the largest producer of A.I. computer chips and now one of the most valuable companies in the world. Amid the frenzy, Blackstone plowed billions more into QTS, increasing its number of leased data centers ninefold in just under four years.

QTS tenants include major technology companies like Google and Meta that are opening up their wallets on A.I. investments. Alphabet recently said it would spend $75 billion this year and Meta up to $72 billion, largely on A.I. infrastructure.

A QTS data center complex under development in Fayetteville, Ga. Elijah Nouvelage/Bloomberg

The complexity and cost of running A.I.-focused data centers stem from the vast amounts of power they guzzle, which can be about 10 to 20 times as much per server or rack as general cloud computing. There is also the need to keep the centers operational 99.999 percent of the day, or the "five nines" in industry parlance. That equates to about five minutes of downtime all year for maintenance or to switch out servers.

Blackstone has branched out from QTS and has been buying up other operators around the globe, including a giant data center company in Australia with operations around Asia, and has teamed up with Digital Realty, another American data center company, to build four more giant campuses in Frankfurt, Paris and Northern Virginia.

Even with the onslaught of new entrants into the data-center market, Blackstone believes it has unique advantages, including more money to invest and ownership stakes in construction and equipment companies that can help get the projects done.

"When you start getting to these very large-scale projects, there are very few who can put all these pieces together," said Nadeem Meghji, global co-head of real estate at Blackstone.

But earlier this year, Blackstone's seemingly invincible bet suddenly looked shaky.

In late January, the Chinese firm DeepSeek said it had figured out a way to build A.I. systems using less power and fewer chips, raising the possibility that there may be less need for these large, expensive data centers.

People in Seoul, South Korea, watched a television report on DeepSeek, a Chinese artificial intelligence start-up. Ahn Young-Joon/Associated Press

The revelation appeared to shatter certain investment ideas about A.I., including the infrastructure bet. Still, within days, Blackstone and its tenants, including Meta and Microsoft, reaffirmed on their quarterly conference calls their need for and commitment to this investment.

The stock market seems increasingly convinced of this, also.

On March 28, CoreWeave, a darling of the A.I. boom, went public. CoreWeave rents out computing capacity to tech companies and runs data centers. The company's initial public offering underwhelmed, with its stock trading far below where its bankers and investors had predicted. But by late May, its stock had more than doubled from the I.P.O. price.

Last month, though, the data center industry was rattled again.

Microsoft said it was pausing the construction of data centers in New Albany, Ohio, where QTS and other operators are building out new centers or have existing ones.

"We really did not have prior notice," said David Edelblute, a government official in Licking County, which includes a portion of New Albany.

Rudy Sahay, the founder of the investment firm Aquarian Holdings, said he had recently passed on a data center deal because the terms made it too easy for tenants to get out of the leases.

The data center in Sterling. QTS announced in March that its founder was stepping down as chief executive. Greg Kahn for The New York Times

Other investors are starting to question how Blackstone and other Wall Street investors in data centers will ultimately exit them. Few investors are as large as Blackstone and have the money to buy such mammoth companies or even individual data centers valued in the tens of billions of dollars, and group deals can be difficult to execute. A core part of the private equity model is that the firms buy companies and sell them within five to seven years so they can return money to their investors.

Karl Kuchel, head of a group at the Australian bank Macquarie that invests in data centers, said it was "an unanswered question" as to whether there would be buyers for these enormous data centers once the private equity firms looked to sell out.

If taking QTS public again is not a viable option, some investors bet that Blackstone will have to find creative ways for investors to get their money out. Blackstone could sell individual data centers, said Sean Klimczak, its global head of infrastructure. Alternatively, he noted, Blackstone doesn't necessarily have to sell the data centers because they're in certain funds that hold investments indefinitely.

One person who has found a profitable exit is Mr. Williams, the QTS founder, who started with one data center in Kansas in 2003.

In March, the company announced that he was stepping down as chief executive. In a statement, Mr. Williams said he planned to return to another one of his companies, Quality Group of Companies as chief executive, and he thanked Blackstone for the opportunity to work and grow together.

As part of his departure agreement, two people briefed on the matter said, Blackstone will pay Mr. Williams $3 billion.

Maureen Farrell writes about Wall Street for The Times, focusing on private equity, hedge funds and billionaires and how they influence the world of investing.

A version of this article appears in print on , Section B, Page 1 of the New York edition with the headline: Data Centers For A.I.: Risk Or Sure Bet?

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Technology, Media & Telecommunications Practice

Investing in the rising data center economy

Private investors have snapped up data centers in recent years, but plenty of other potential investment opportunities in the sector's value chain may be going unnoticed.

This article is a collaborative effort by Srini Bangalore, Arjita Bhan, Andrea Del Miglio, Pankaj Sachdeva, Vijay Sarma, Raman Sharma, and Bhargs Srivathsan, representing views from McKinsey's Technology, Media & Telecommunications Practice.

January 2023

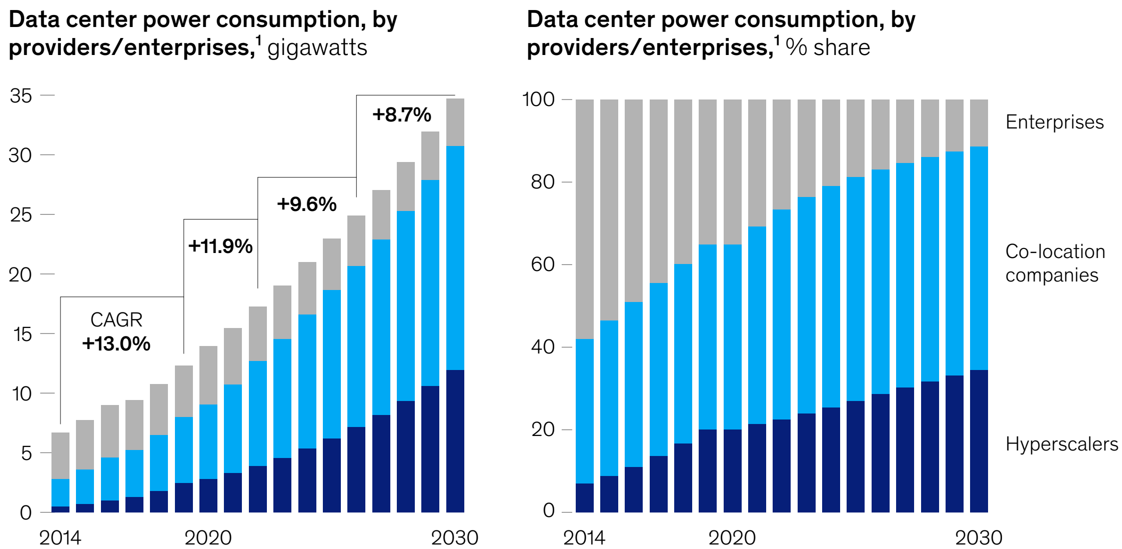
The explosion in demand for data centers has attracted the attention of investors of all types—growth capital, buyout, real estate, and, increasingly, infrastructure investors. In the US market alone, demand—measured by power consumption to reflect the number of servers a data center can house—is expected to reach 35 gigawatts (GW) by 2030, up from 17 GW in 2022, according to McKinsey analysis (Exhibit 1). The United States accounts for roughly 40 percent of the global market.

Data centers are typically owned and operated either by big companies (such as cloud vendors, banks, or telcos) for their own purposes or by co-location companies. The latter lease out the space and typically provide network capacity and power, as well as the cooling equipment that keeps down server temperatures. Tenants bring their own IT equipment. Data centers have attracted the interest of investors, often because of the steady, utility-like cash flows and risk-adjusted yields.[1] In 2021, there were 209 data center deals, with an aggregate value of more than $48 billion, up some 40 percent from 2020, when the deals were worth $34 billion. In the first half of 2022, there were 87 deals, with an aggregate value of $24 billion. From 2015 to 2018, private equity buyers accounted for 42 percent of the deal value. Their share increased to 65 percent from 2019 to 2021 and to more than 90 percent in the first half of 2022.[2]

Several factors could limit this trend, however. First, higher interest rates raise the cost of funding

Exhibit 1

US data center demand is forecast to grow by some 10 percent a year until 2030.



[1]Demand is measured by power consumption to reflect the number of servers a data center can house. Demand includes megawatts for storage, servers, and networks.

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[1] Relatively few data center operators remain publicly owned. According to NAREIT, as of October 31, 2022, the dividend yield stands at 3.14 percent, and the 2021 total return at 25.47 percent.

[2] "Private equity is driving a boom in data center M&A deals," Synergy Research Group, June 22, 2022.

deals, though this is not limited to only data centers. More specifically, multiples and forward price-to-earnings ratios for co-location companies have been relatively high, boosted by competition to snag the diminishing number of potential acquisition targets for private investors and for co-location companies keen to expand.

In addition, the operating margins of co-location companies are under pressure from prominent cloud vendors, including Amazon Web Services and Google Cloud. These have long been major customers for co-location companies but also continue to own and build their own world-class centers.[3] As a result, they are signing shorter-term contracts and are often in a strong position to demand favorable leasing terms. Moreover, if this strategy means that co-location companies will no longer be long-term owners and operators of data centers but more akin to developers, the market will open up for other competitors. Real-estate companies, for example, could increasingly build or lease out space for their tenants to equip and use.

But this possibility does not mean that the sector lacks value-creating investment opportunities. As Exhibit 1 shows, co-location companies will continue to have a strong position in the market. Hyperscalers still need them to meet fast-growing demand, and smaller enterprises depend on their specialist services. That helps explain why three investment groups are in the running to acquire Global Switch.[4] However, many investors may not have considered the upstream opportunities in a complex value chain. Here we explain where investors might start to look.

Data centers have four main components: the facility itself; the industrial equipment, including the mechanical, electrical, and plumbing (MEP) gear; the IT hardware; and the software. There are also opportunities in data center operations—the management of facilities and IT services, such as hosting and infrastructure as a service (IaaS). Other services, such as power and connectivity, present opportunities, too. Potential investments lie across this value chain, but in four areas demand is particularly high (and not matched by supply) or innovation is especially likely to create value.

Sustainable (or green) energy

Data centers are big energy consumers—a hyperscaler's data center can use as much power as 80,000 households do. Pressure to make data centers sustainable is therefore high, and some regulators and governments are imposing sustainability standards on newly built data centers.[5] This development gives investors opportunities to help data centers secure carbon-free energy supplies.

In fact, the use of renewable energy is a critical component of the hyperscalers' strategies. Thanks to carbon offsets, Apple, Google, and Meta, for example, were all carbon neutral by 2020. They and other hyperscalers have committed themselves to using only carbon-free energy by 2030. Co-location companies are also under pressure, not least from some of their customers, to meet sustainability goals. A former executive at a hyperscaler told us that the sustainability record of co-location companies was a significant consideration in deciding which ones to work with.

To reach carbon-free energy goals, data center owners are signing power purchase agreements (PPAs) with suppliers of renewable energy. Meanwhile, hyperscalers are starting to fund the building of renewable-energy plants in the face of soaring prices caused by supply shortages.[6] In the United Kingdom, for example, Amazon has supported Scottish Power's wind farm and is purchasing its entire 50-megawatt (MW) output.[7]

3 McKinsey analysis.
4 Dan Swinhoe, "Stonepeak and Gaw drop out of Global Switch bidding, three companies still in running," DCD, November 22, 2022.
5 Singapore and the Netherlands are examples.
6 Dan Swinhoe, "Power purchase agreement prices up nearly 50 percent in Europe over last year," DCD, July 14, 2022.
7 "Amazon's first Scottish wind farm project comes online," Amazon News, October 28, 2021.

Yet such moves will not suffice if using only renewable energy is the goal. The first problem is intermittency. Solar power is generated only in the daytime, and wind power depends on the weather, so fossil-fuel supplies often supplement power from renewable PPAs. One emerging solution is "24/7" PPAs, which commit themselves to matching each hour of electricity consumption with a combination of carbon-free supplies and, quite important, stored renewable energy. These contracts come at higher prices, however, not least because current storage technologies are expensive. The levelized cost of electricity from a system that combines wind, solar, and lithium-ion (Li-ion) battery storage typically exceeds $200 per megawatt-hour. Long-duration storage solutions that deploy hydrogen and green-ammonia energy could push that below $100, but these technologies remain at a relatively early stage of development.[8] Backup power is another issue, since many data centers still use diesel generators during power outages. Li-ion batteries are the most developed carbon-free backup solution but can prove expensive over long periods.

All of this presents opportunities for investors. Not all co-location providers have the scale to procure renewable power either through PPAs or investments in power plants. Investors with smaller data centers could aggregate their purchasing power to optimize energy procurement and storage. Some might also consider investing in renewable-energy plants that could supply consortiums of smaller players.

Other potential technology and R&D investments include more stable renewable-energy technology and sources (such as geothermal and wave energy) to facilitate zero-carbon backup power and storage solutions. Investors might even offer to pilot new solutions in data centers they own.

Cooling and energy consumption

Climate change and unpredictable weather events, pressure to decarbonize data centers, and increasingly powerful computers offer investment opportunities in cooling and energy efficiency technologies for data centers.

Data center equipment, often consisting of thousands of servers, must be cooled to work efficiently. Indeed, the capacity of a data center is dictated by how well it cools the servers—the more closely they can be stacked, the more productive the square footage. Efficient cooling is therefore a crucial driver of a data center's profitability. Cooling accounts for some 40 percent of a data center's energy consumption.[9] The cost of downtime from overheating can be high.

Cooling technology has improved rapidly over the past decade. Most large data centers have replaced old air-conditioning-like systems that keep entire rooms cool with in-row or rotodynamic heater-based cooling designs: heat emitted from servers is drawn away by fans and then cooled with water or a refrigerant. Yet even better performance is required because today's more advanced systems can struggle to control the temperatures associated with global warming. Google and Oracle, for instance, both faced downtime during a heatwave in Europe this past summer.

Higher computing power and innovative chip designs are also putting more demand on cooling systems by raising the power density: the energy consumption of the equipment stored in racks. Their average power densities have more than doubled over the past six to seven years and continue to rise.[10] The density of a single rack can be as high as 20 to 30 kilowatts in specific high-performance environments. Space constraints—especially for smaller edge-computing data centers in urban areas—also raise demand for systems with higher power densities.

[8] "Decarbonizing the grid with 24/7 clean power purchase agreements," McKinsey, May 11, 2022.
[9] McKinsey analysis.
[10] Andy Lawrence, "Density is rising," Uptime Institute, December 7, 2020.

Data centers need to use energy more efficiently as well. Power usage effectiveness (PUE)—the amount of power the computing equipment in a data center uses relative to its total energy consumption—fell considerably from 2007 levels, but progress has flattened over the past decade (Exhibit 2).[11] Even the hyperscalers that deploy advanced cooling designs and technologies struggle to improve significantly: the reported PUE of Google's data centers has fallen only incrementally during the past seven to eight years, for example.[12]

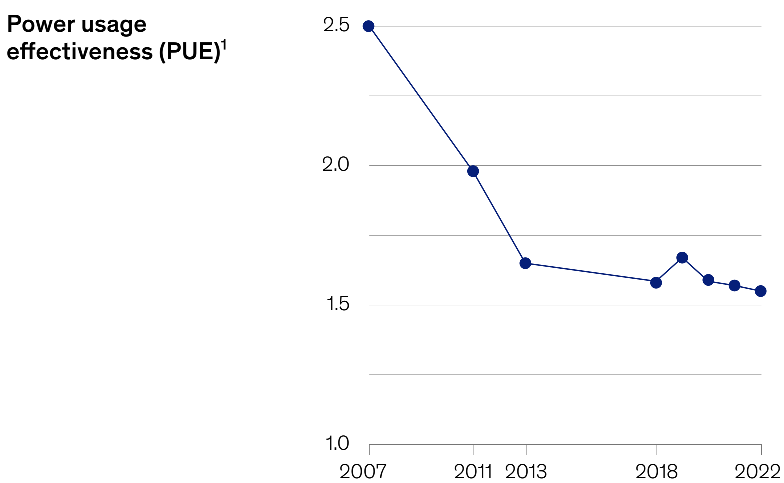
To address these challenges, companies are developing and deploying several technologies, including immersion cooling, artificial intelligence and machine learning, and the use of waste heat (see sidebar, "Cooling and energy efficiency technologies"). Yet extensive investment is still required to make progress in R&D and in deployment at scale. In some instances, collaboration across the value chain will probably be needed: for example, full-immersion cooling, which submerges servers in a coolant, could require changes to chip packaging; the form factors of servers; building layouts, materials, and design; and MEP systems. An investor with data center assets might vertically integrate components of the value chain by, for example, investing in a cooling-technology company to prove a concept and test the solution.

Constructing prefab and modular data centers

Rising demand for new data centers is also creating potential investment opportunities in the fragmented prefabrication and modular (PFM) sector. According to the Synergy Research Group, in 2022 hyperscalers alone allocated some

Exhibit 2

Gains in power usage efficiency have stalled during the past decade.



[1]A measure that shows the amount of power used by the computing equipment in a data center relative to its total energy consumption. The closer PUE is to 1, the more efficient a data center's power usage is.
Source: Uptime Institute Intelligence

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[11] *Uptime Institute Global Data Center Survey Results 2022*, Uptime Institute, September 14, 2022.
[12] "Efficiency," Google Data Centers.

$9 billion to build more capacity—a sum expected to grow by more than 4 percent a year until 2030 (Exhibit 3). Such plans face headwinds, however: the labor market is tight, commodity prices volatile, inflation high, and supply chains constrained, so global capital costs for construction projects have risen by at least 6 percent since 2020.[13]

As a result, hyperscalers have turned increasingly to PFM solutions that enable parts of the construction process to take place off-site. Done well, PFM not only cuts construction times but also reduces costs and improves safety, quality, and sustainability, since more work takes place in controlled manufacturing settings. One company recently cut the cost of building a 45-MW facility in Europe by 20 percent and slashed construction time to 11 months (from 17) by using prefabricated components for the building, as well as modularized components for the electrical and cooling systems.

There are four types of prefabricated or modularized solutions:

— the prefabrication of structural and architectural components, such as concrete beams, walls, slabs, facades, and precast underground culverts

[13] McKinsey Capital Analytics.

Cooling and energy efficiency technologies

To improve the efficiency of cooling systems and reduce energy consumption in data centers, several technologies are now under development.

Immersion cooling. New approaches include full-immersion and direct-to-chip/cold-plate cooling. In the former, IT equipment (such as a server) is immersed entirely in a nonconductive and nonflammable di-electric liquid that acts as a coolant and dissipates heat generated by the equipment. In the latter (and more targeted) approach, a metal plate (or heat sink) is used for high-thermal-emission components (such as chips) in the servers. This approach transfers the heat and then cools it using a liquid coolant. By maintaining consistent, uniform temperatures, full-immersion cooling can cope with higher power densities (upward of 100 kilowatts) and raise the average performance of central processing units by as much as 40 percent.[1] Riot Platforms uses immersion technology at a Bitcoin-mining farm in its Whinstone facility in Texas,[2] and hyperscalers are developing and testing it. But the widespread use of these technologies will require collaboration between IT manufacturers and infrastructure owners.

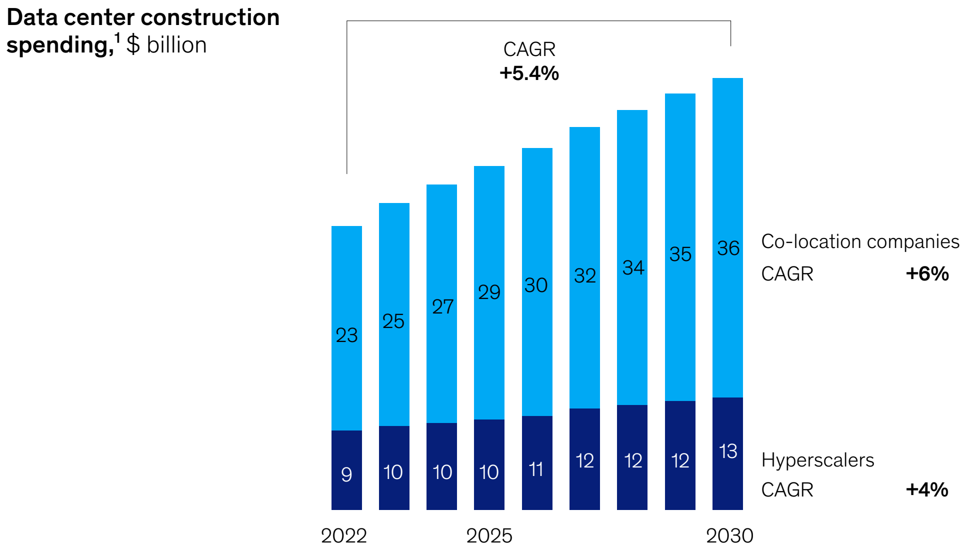
Artificial intelligence and machine learning. Hyperscalers such as Google have used artificial intelligence/machine learning (AI/ML) algorithms to focus cooling where it is most needed, depending on factors such as workload intensity and changing power loads across racks. Early adopters have reported 20 to 30 percent reductions in power usage effectiveness. AI/ML applications have also balanced the load on uninterruptible-power-supply units by changing power routes to servers throughout the day to optimize cooling and save energy.

Waste-heat applications. To reduce a data center's carbon footprint, these applications use heat from data centers for other purposes, such as district heating. Amazon uses recycled heat from a data center in Ireland to supply district heat in Dublin, for example, and Facebook says that the heat from its Danish data center is warming 6,900 homes.[3]

[1] McKinsey analysis.
[2] "Riot announces first industrial-scale immersion-cooled bitcoin mining operation," Riot Platforms press release, October 19, 2021.
[3] Lauren Edelman, "Facebook's hyperscale data center warms Odense," Meta, July 7, 2020.

Exhibit 3

Global spending on the construction of data centers is forecast to reach $49 billion by 2030.



[1]Includes construction spending by providers. Excludes enterprise spending and any other capital expenditure outside of construction (such as equipment).
Source: Synergy Research Group

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- skid-mounted MEP equipment: metal racks for mounting and connecting mechanical, IT, power, and cooling components and systems
- enclosed MEP modules, which mount and connect the same kind of equipment, but in a cabinet
- all-in-one data centers: turnkey data centers, which are feasible only for smaller facilities of 1.0 to 1.5 MW.

Some companies manufacture parts for solutions and others integrate them. A few well-established players serve a broad range of industries; others work specifically with data center operators. But a long tail of start-ups focus on small slivers of this industry. They are too small to serve large companies, and that holds back demand. Investors in manufacturers or integrators of PFM components could help these companies expand their reach and improve economies of scale.

Edge computing

Although enterprises are rapidly shifting vast amounts of their work to the public cloud, they are also growing more knowledgeable about what *not* to store there. Applications (for instance, autonomous driving) that require real-time insights at very low latencies might be better conducted close to the data's source. The cost of transferring large volumes of data to and from the public cloud can also favor edge computing. So do data privacy and residency regulations that require certain types of data to be stored near their point of origin.

All this explains the growing size of the addressable market for edge computing. According to IDC, the worldwide spending of enterprises and service providers on hardware, software, and services for edge solutions was projected to reach $176 billion in 2022 (an increase of 14.8 percent from 2021) and $274 billion in 2025.[14]

Two types of investment opportunities related to data centers stand out. The first is real estate. Demand for edge computing must be met from smaller data centers, often located in urban areas close to customers, rather than huge facilities in far-off locales. The second is technology. The components of the edge-computing tech stack (the hardware, connectivity, platforms, and software) are not new. The challenge is how to deploy and architect them at the edge—how artificial-intelligence capabilities can be brought there, for example, or how to deploy and manage platforms.

Not surprisingly, the big edge providers (such as hyperscalers, telcos, and large systems integrators) are acquiring or investing in start-ups in the space. In March 2022, for instance, T-Mobile invested $40 million in Spectro Cloud to promote innovation in Kubernetes management. In April, Google Cloud acquired MobiledgeX, an edge-computing management specialist aiming to develop a standard orchestration layer for edge-computing assets. Private investors interested in data centers could also consider investments in edge technology.

As demand for data centers increases, investments in companies that operate them and in co-location companies remain an option. Yet potentially attractive opportunities lie in other parts of the data center value chain. Investors might focus on individual elements (such as green-power generation or immersion cooling) or invest where elements intersect—modular solutions for edge data centers, for example, or carbon-free edge data centers. Investors that already own data center assets could also consider vertically integrating critical elements across the value chain.

Investment activity in some areas, such as procuring green energy for data centers or cooling solutions, may be picking up. However, these are still far from the mainstream, leaving considerable untapped potential. Since the risk/return profiles differ from those for the acquisition of a data center, these areas will probably appeal to different sets of investors, depending on their investment objectives. With data centers now playing such a central role in the economy, it makes sense to consider the entire value chain.

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The authors wish to thank Katy Bartlett, Luca Bennici, Marcel Brinkman, Vladimir Cernavskis, Rishi Gupta, Arpit Kaur, Matt Linderman, Andrew Mullin, Shaila Narang, Jakob Österberg, Nick Padgett, Jürgen Sailer, Lorraine Salazar, Nestor Sepulveda, Shashank Sharma, Even Skjellaug, Christoph Sohns, Adithya Sukumar, Shally Venugopal, and Philippe Wrobel for their contributions to this article.

Designed by McKinsey Global Publishing

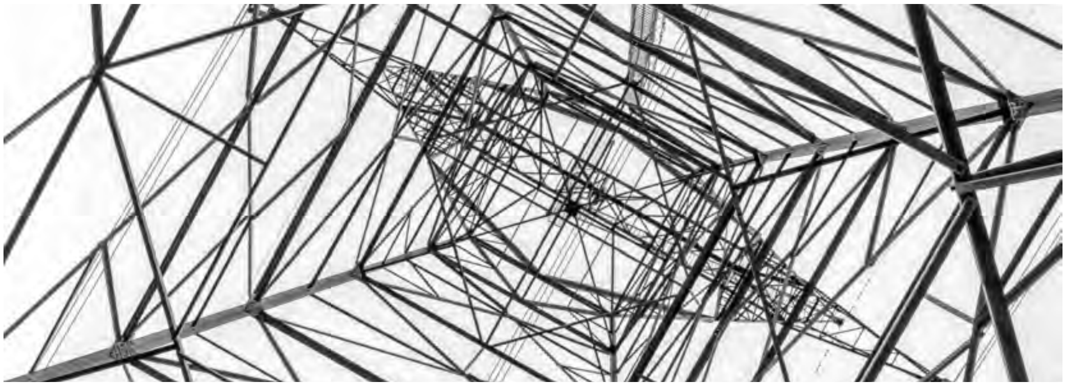
[14] "New IDC spending guide forecasts double-digit growth for investments in edge computing," IDC, January 13, 2022.

North America Regulated Utilities

Capex and climate change pressures credit quality

January 14, 2025

This report does not constitute a rating action.



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What's changed?

Lower ratings headroom. A high percentage of companies are operating with only minimal financial cushion from our downgrade threshold.

Rising capital spending, higher cash flow deficits, and increased wildfire risks led to downgrades outpacing upgrades for the fifth consecutive year.

Data centers spur electricity sales growth at about 1% annually, which will provide modest support to credit quality.

What are the key assumptions for 2025?

High cash flow deficits of about $100 billion, which could harm financial performance if not funded in a credit-supportive manner.

Robust dividends of about $50 billion for 2025 and at a dividend payout ratio of about 60%.

Record amount of hybrid securities. The industry issued $26 billion of them in 2024, and we expect this trend will persist.

What are the key risks around the baseline?

Rising wildfire risks stemming from climate change.

Tax legislation could weaken financial measures if the new Republican administration lowers the corporate tax rate, reduces tax credits, or eliminates their transferability.

Common equity issuance is below our base-case expectations, and has been for the last several years, leading to weaker financial measures.

Ratings Trends: North America Regulated Utilities

Chart 1

Ratings distribution

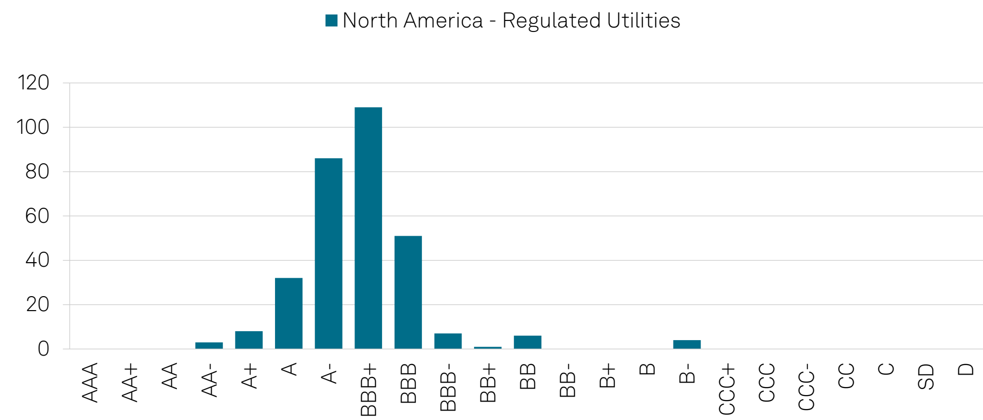


Chart 2

Ratings outlooks

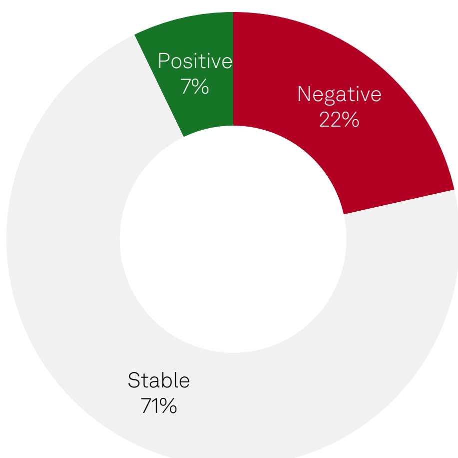
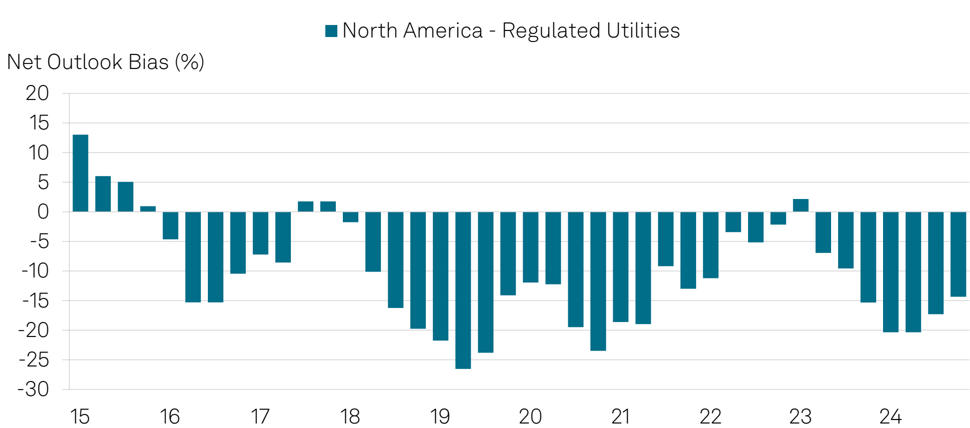


Chart 3

Ratings outlook net bias



Source: S&P Global Ratings. Ratings data measured at quarter-end.

Industry Credit Metrics: North America Regulated Utilities

Chart 4

Debt / EBITDA (median, adjusted)

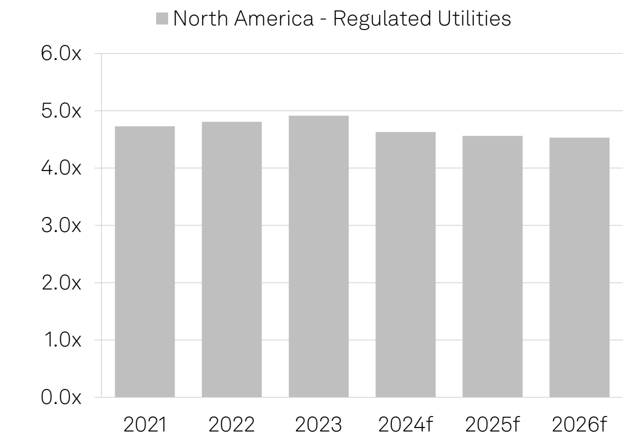


Chart 5

FFO / Debt (median, adjusted)

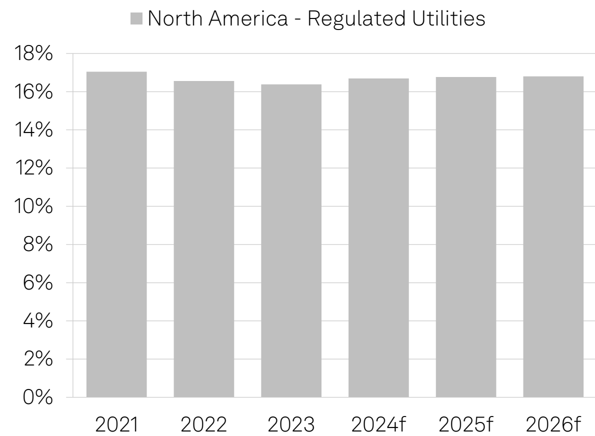


Chart 6

Cash flow and primary uses

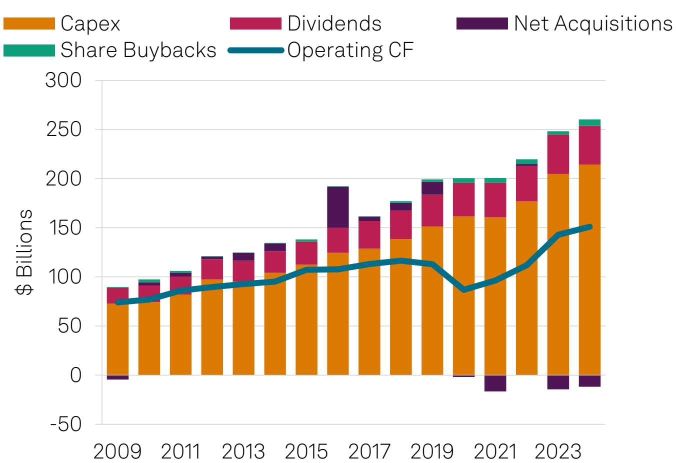
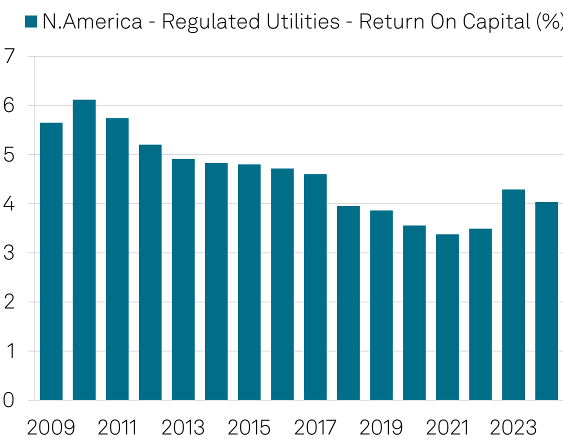


Chart 7

Return on capital employed



Source: S&P Global Ratings, S&P Capital IQ.
Revenue growth shows local currency growth weighted by prior-year common-currency revenue share. All other figures are converted into U.S. dollars using historic exchange rates. Forecasts are converted at the last financial year-end spot rate. FFO—Funds from operations. Most recent (2024) figures for cash flow and primary uses and return on capital employed use the last 12 months' data.

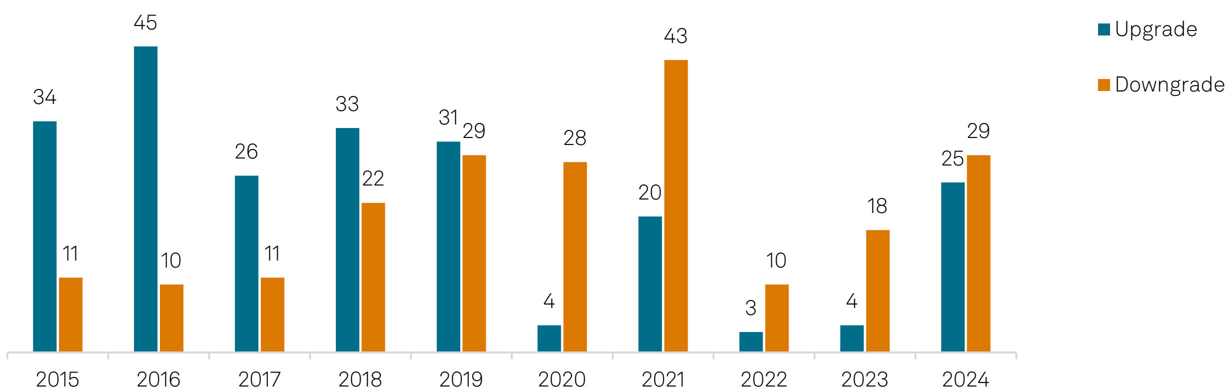
Industry Outlook

Ratings trends and outlook

In 2024, downgrades among North America's investor-owned regulated utilities outpaced upgrades for the fifth consecutive year (see chart 8). Most were directly attributable to rising wildfire risks, robust capital spending, and challenging regulatory constructs. We expect these risks will persist for 2025, further pressuring the industry's credit quality.

Chart 8

North America regulated utilities' upgrades and downgrades



Source: S&P Global Ratings.

Main assumptions about 2025 and beyond

1. Record capital spending.

The industry is heavily investing in safety, reliability, energy transition, and data centers. We expect this spending will exceed $300 billion before the end of the decade.

2. Management of regulatory risk.

This includes constructive rate case orders, minimizing regulatory lag, and earning the authorized return on equity (ROE).

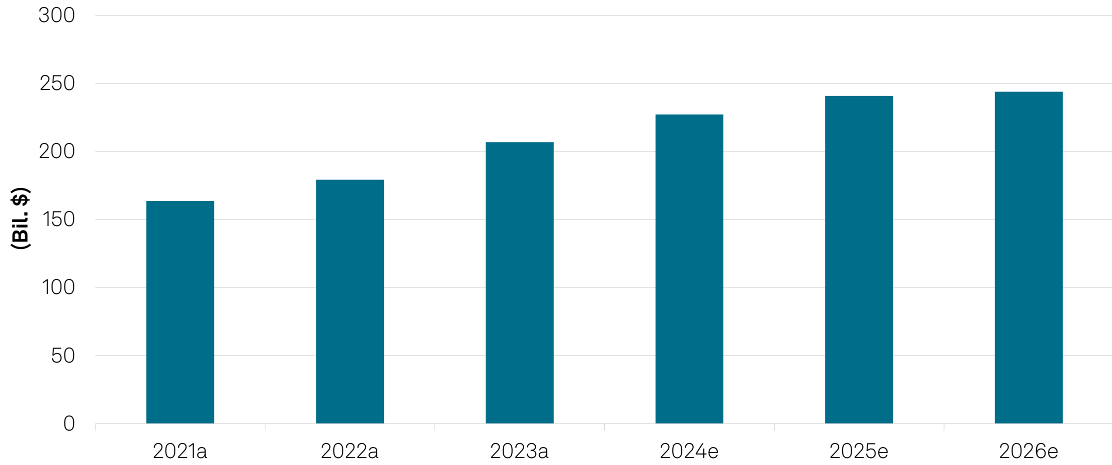
3. Climate change increases risks.

The growing frequency of devastating physical events, including hurricanes, storms, and wildfires, is elevating the industry's credit risks.

Capital spending continues to break records. We expect capital spending for North America's electric, gas, and water utilities will grow by a compound annual growth rate (CAGR) of about 10%. Accordingly, we expect 2025 capital spending to reflect about $240 billion (see chart 9). To date, the industry's capital spending has been primarily focused on safety, reliability, and energy transition.

Chart 9

North America regulated utilities' rising capital expenditures

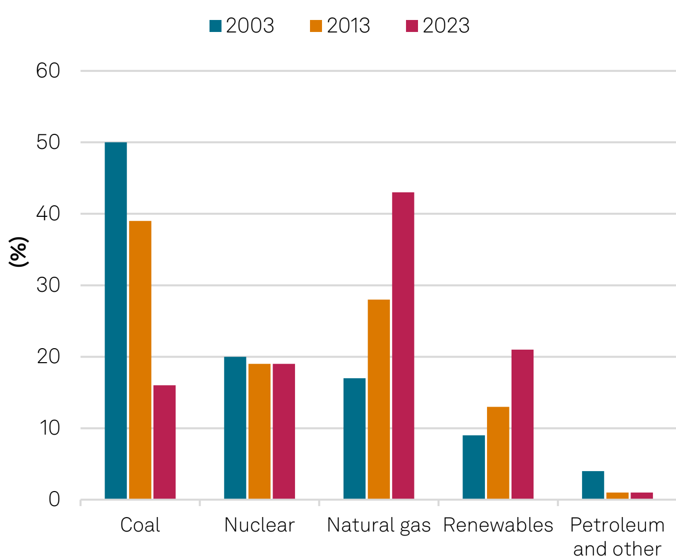


a—Actual. e—Estimate. Capital expenditures represent North American investor-owned electric gas, and water utilities.
Source: S&P Global Ratings.

Energy transition remains key. Over the past decade the industry has invested billions on reducing its reliance on coal-fired generation by about 50% (see chart 10), and today, coal represents only about 15% of total electric generation. Most of the coal was replaced with natural gas, which has about half the carbon emissions. We expect the industry will replace most of its remaining coal-fired generation by about 2030 with renewables and batteries, further reducing its carbon and greenhouse gas (GHG) emissions. The industry has reduced its GHG emissions by nearly 30% over the past decade (see chart 11), and we expect it will reduce them by another 30% by 2035.

Chart 10

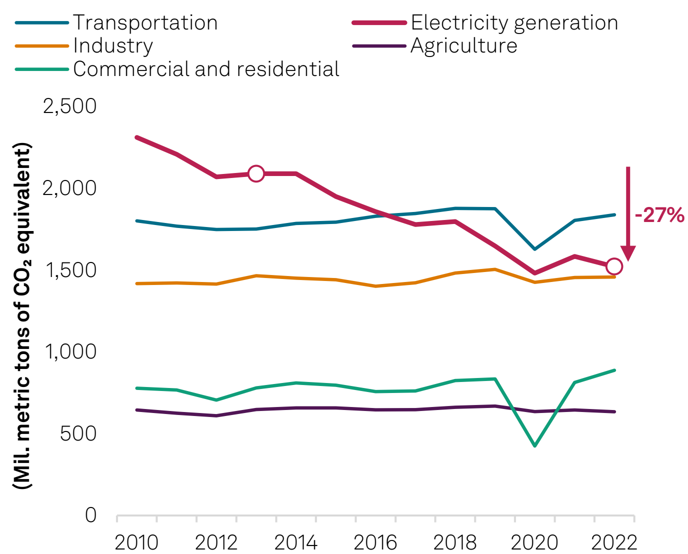
U.S. generation transformation



Source: U.S. Energy Information Administration.

Chart 11

GHG emissions by economic sector (2010-2022)

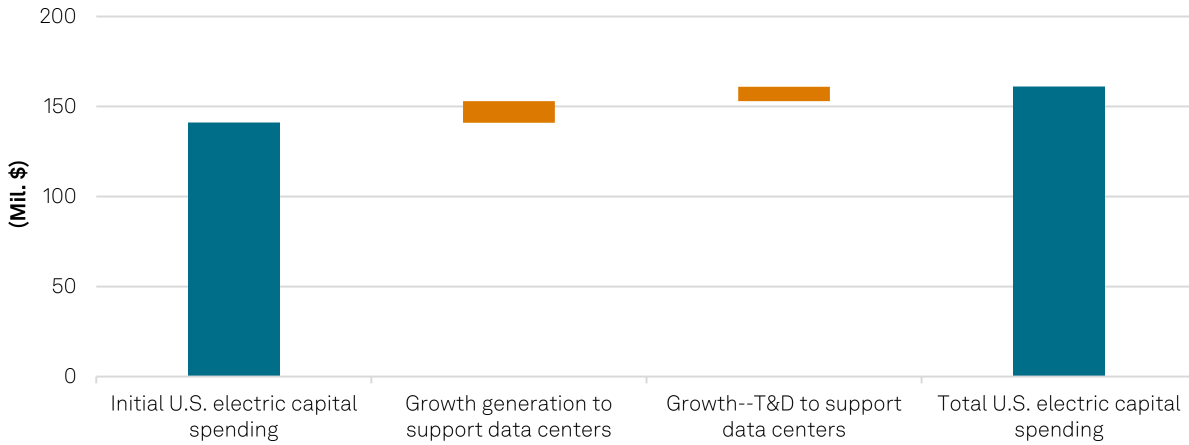


Source: U.S. Environmental Protection Agency.

Data center growth is relatively new, and our current base-case assumptions do not fully incorporate the incremental spending necessary for it. The higher spending for data centers is more likely to begin in 2026. Accordingly, 2026 capex could potentially increase by about another 15% above our current base case (see chart 12).

Chart 12

Data center growth will increase U.S. electric utility annual capital spending by about 15%

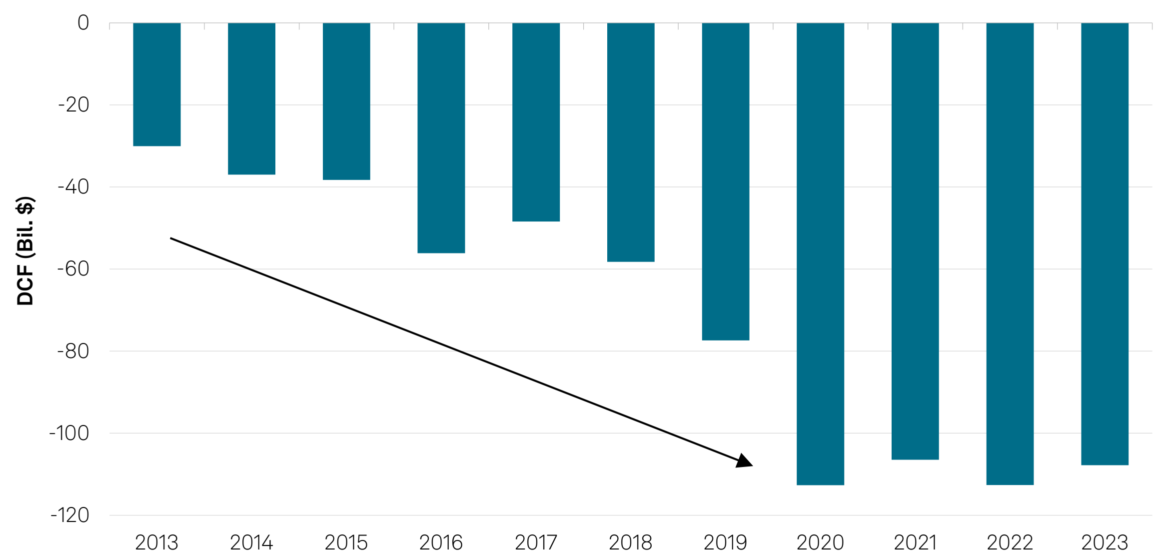


T&D—Transmission and distribution. Source: S&P Global Ratings.

Cash flow deficits will rise as a result, increasing the pressure on the industry's credit quality. Over the past decade the industry's cash flow deficits have grown from about $50 billion to consistently over $100 billion (see chart 13), and we expect this trend will continue.

Chart 13

North America regulated utilities' cash flow deficits

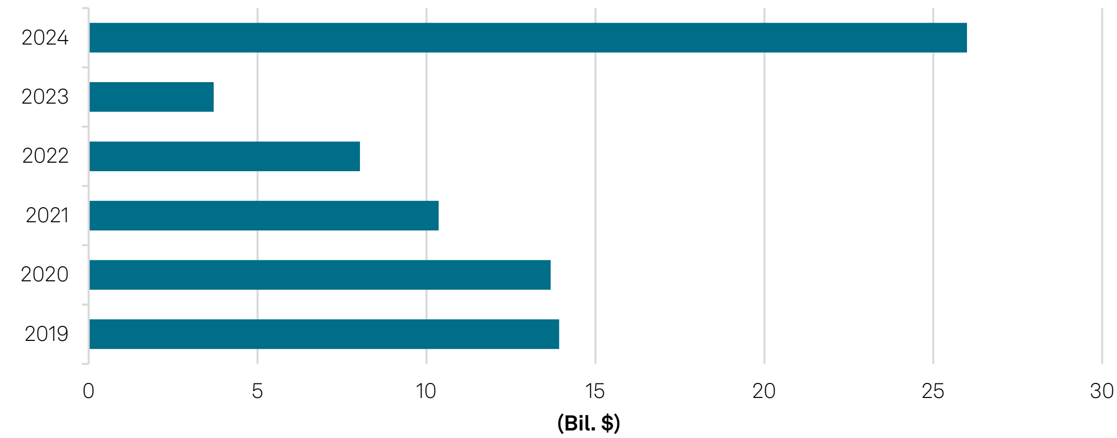


DCF—Discretionary cash flow. Sources: S&P Global Capital IQ, S&P Global Ratings.

Hybrid security issuance reached an all-time high of about $26 billion in 2024, far exceeding the previous record of about $14 billion in 2019 (see chart 14). We expect the industry will maintain this level of issuance in 2025 given its increased capital spending. This robust issuance supported the industry's 2024 financial measures because we typically assess hybrid securities as more credit supportive than debt, with most of these securities having intermediate (50%) or high (100%) equity content.

Chart 14

North America regulated utilities' annual hybrid securities issuance

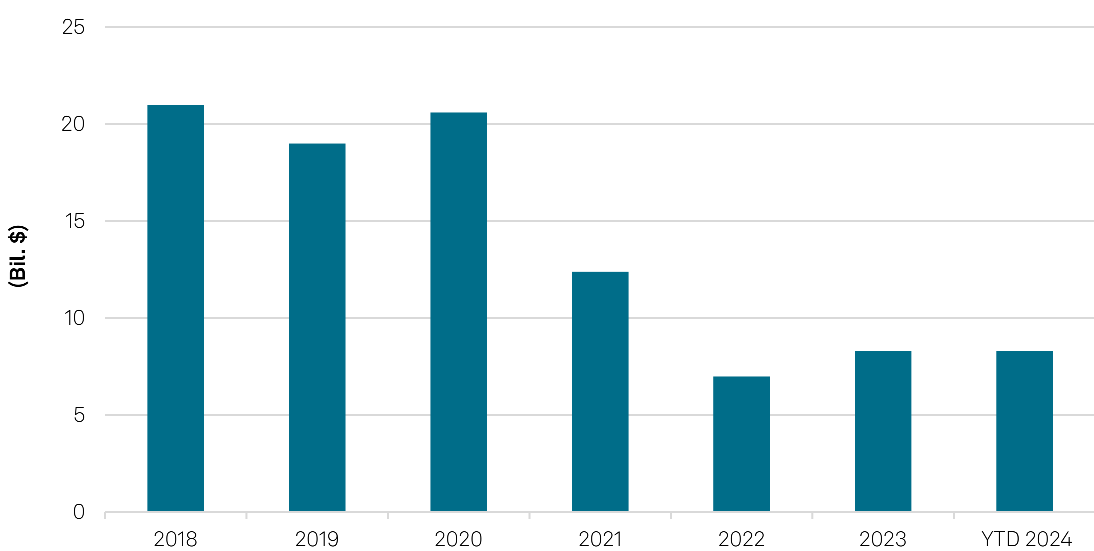


Sources: S&P Global Ratings, S&P Global Market Intelligence.

Common equity issuance has been weak and consistently below our expectations since 2021, pressuring the industry's financial measures. It raised only about $8 billion in 2024, and we estimate that the full year will reflect only about $10 billion. This is well below the industry's average run rate of about $20 billion annually between 2018-2020 (see chart 15). We expect 2025 common equity issuance will again be relatively weak and more reflective of 2024 levels. Without significantly more common equity issuance, we expect the industry's financial measures will continue to weaken, albeit gradually, supporting our negative outlook.

Chart 15

North America regulated utilities' common equity issuance



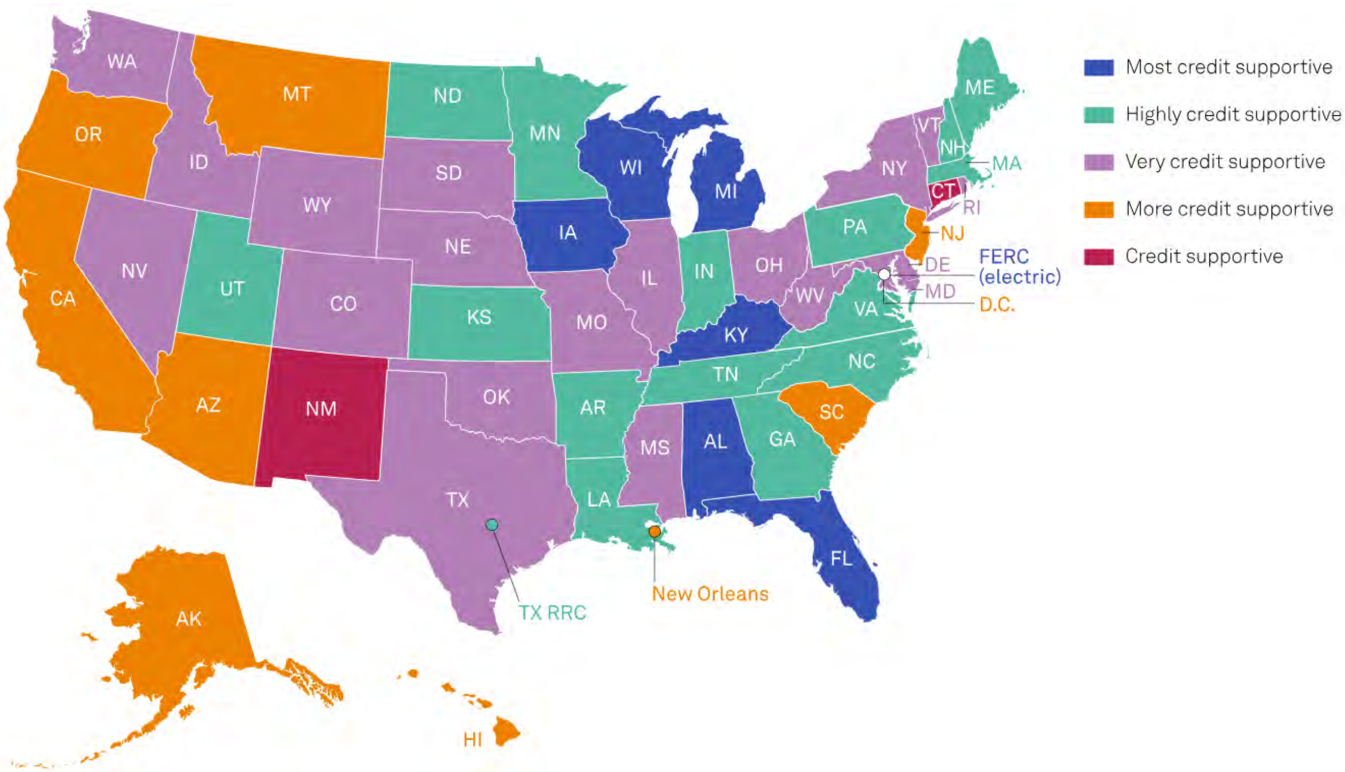
YTD—Year-to-date as of Dec. 15, 2024. Sources: S&P Global Ratings, S&P Global Market Intelligence.

Effective management of regulatory risk will continue. We assess all North America's regulatory jurisdictions as credit supportive or better, reflecting the industry's generally stable and predictable cash flows (see chart 16). Over the past decade much of the industry has implemented regulatory mechanisms such as decoupling, interim rates, capital trackers, formula rate plans, forward test years, muti-year rate case filings, and regulatory riders to significantly improve cash flow stability while minimizing regulatory lag (that is, the timing difference between when a utility incurs costs and when it's recovered from ratepayers).

Chart 16

Regulatory assessment by state

As of November 2024



Source: S&P Global Ratings.

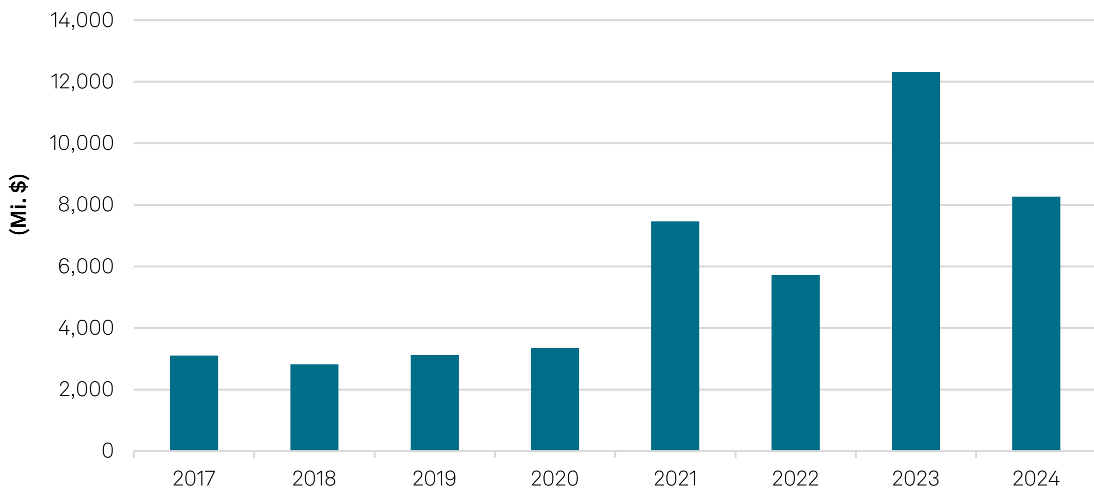
In general, we expect utilities will operate in a regulatory jurisdiction that is supportive of their credit quality by allowing for the full recovery of all their operating and capital costs in a timely manner. We also expect the regulatory jurisdiction will provide a consistent and predictable regulatory framework that results in cash flow stability. Our view of the industry's regulatory constructs supports the industry's mostly investment-grade ratings despite the industry continuing to operate with material cash flow deficits.

Recently, we revised downward our assessment of Connecticut’s regulatory construct to credit supportive from more credit supportive. We now expect the state's regulated utilities will be increasingly subject to below-average authorized ROEs, regulatory lag, and an inconsistent ability to earn their lower authorized ROEs. These developments will increase the utilities' cash flow volatility, decrease the stability of their financial performances, and weaken their ability to consistently manage regulatory risk. Other regulatory jurisdictions that we continue to carefully monitor include Arizona, Colorado, District of Columbia, Illinois, Maryland, Michigan, New Mexico, Texas, and West Virginia.

Regulatory rate case order increases have substantially risen over the past four years, reflecting the industry's robust capital spending. Rate case increases for 2021-2024 have increased by more than 2.5x compared to 2017-2020 (see chart 17), and there are more than 100 U.S. rate cases pending, for which utilities are requesting over $16 billion more in revenue. This is in line with our base case that this year's rate case orders will again be robust and most likely in the top three years for rate case order increases.

Chart 17

U.S. rate case orders

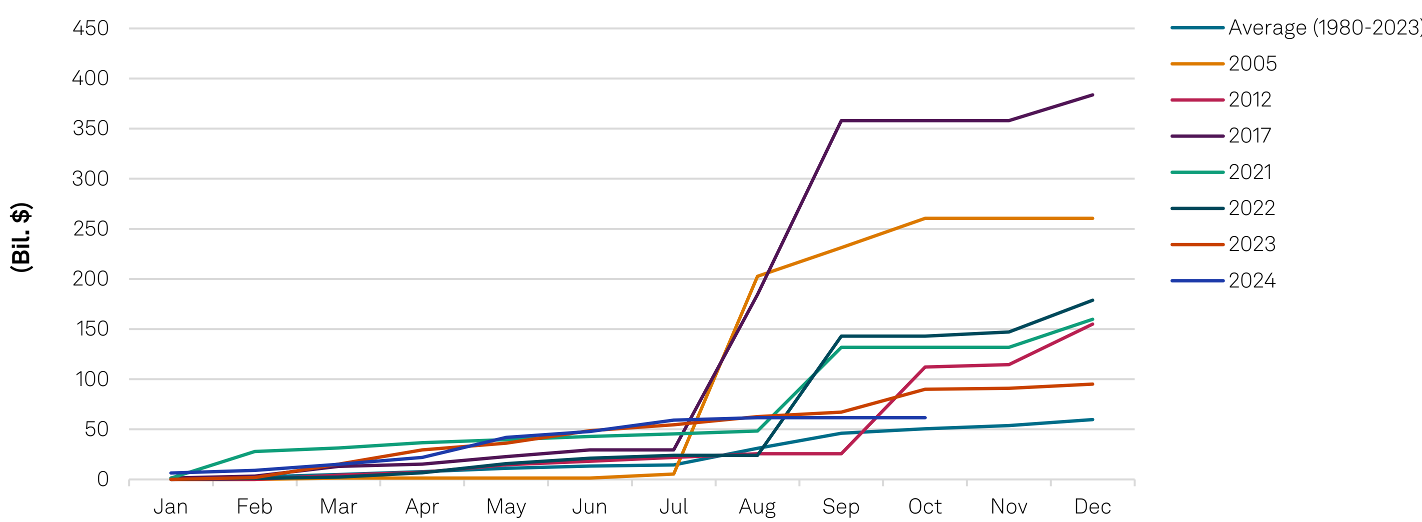


Source: S&P Global Commodity Insights.

Utilities' exposure to physical risks are increasing. According to the National Oceanic and Atmospheric Administration (NOAA), on an inflation-adjusted basis, 2021 and 2022 represent two of the most destructive years for extreme weather events since 1980 (see chart 18). We assume these trends will persist, magnifying physical risks for the utility industry.

Chart 18

U.S. billion-dollar weather disaster year-to-date event cost (CPI-adjusted)



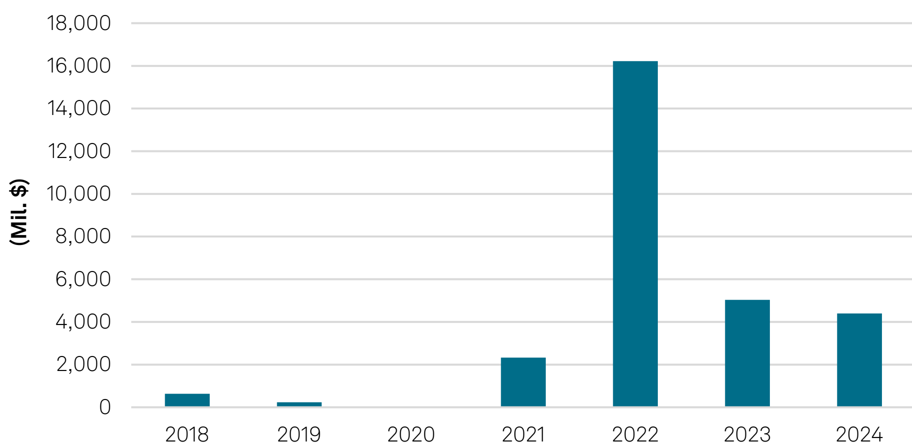
Source: National Ocean and Atmospheric Administration.

Drier, hotter weather has increased the acreage designated as high-fire-risk across the U.S. This is already taking a toll on credit ratings. For example, in 2024 we downgraded parent Xcel Energy Inc. and subsidiary Southwestern Public Service Co. (SPS) because of the scale and severity of the wildfires in the Texas panhandle, which highlights their increasing wildfire exposure. Overall, because of climate change, we expect the industry's wildfire risk will increase.

Securitization increased, which we assess as supportive of credit quality (see chart 19). Securitization allows for the issuance of debt secured by a non-bypassable charge to the customer's bill, allowing the utility to fully recover storm-related costs at a lower interest rate for customers. Because the debt is secured by the high likelihood of customers paying their bills, the associated interest costs are typically lower. We often deconsolidate such debt, resulting in stronger credit measures.

Chart 19

S&P Global Ratings-rated utility-related securitization issuance (2018-2024)



Source: S&P Global Ratings.

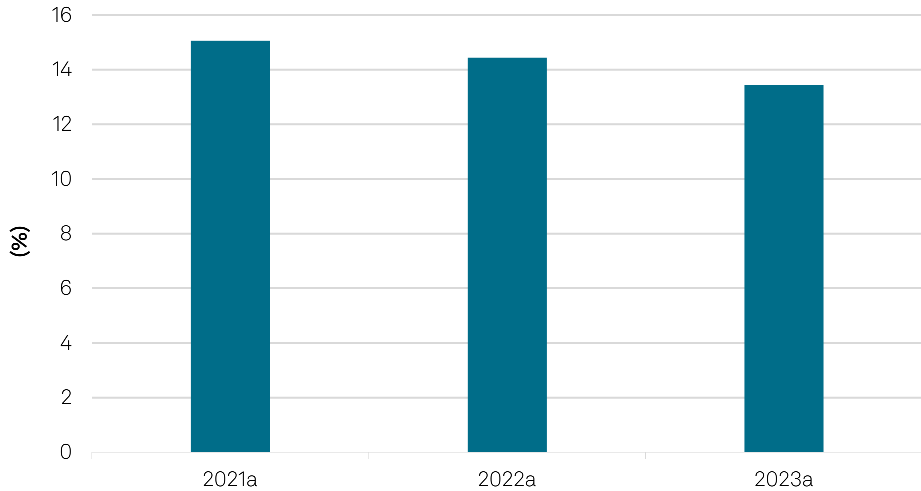
We expect securitization will remain an effective tool that the industry will continue to use. Our base case includes increasing severe natural disasters and weather events as well as continued efforts to decarbonize the energy sector, which sometimes requires securitization to fully recover under-depreciated retiring fossil-fuel generating plants.

Credit metrics and financial policy

We expect rising capital spending and increasing cash flow deficits that are not sufficiently funded in a credit-supportive manner will continue to pressure the industry's financial performance. Its average funds from operations (FFO) to debt was about 15% in 2021 and has gradually fallen to about 13.5%, primarily reflecting rising leverage (see chart 20). Given our expectations for continued increasing capital spending over the next decade, we expect financial performance and credit quality will continue to be pressured.

Chart 20

North American regulated utilities' average FFO to debt



a—Actual. Source: S&P Global Ratings.

Key risks or opportunities around the baseline

1. Wildfire mitigation efforts.

Wildfire risk mitigation, while clearly a credit positive, may not fully address the threats associated with extreme weather events.

2. Data centers and sales growth.

Data center electricity demand will likely boost revenues at North American investor-owned regulated utilities and provide modest support for the industry's credit quality.

3. Managing the customer bill.

The average electric customer bill is about 2% of U.S. median household income, which represents good value for customers relative to other typical household bills. Preserving this value is critical for the industry to maintain credit quality.

Wildfire risk has expanded. Recent events in the Northeast U.S. lead us to believe wildfire risk has spread and now potentially affects nearly every utility across North America. (About 15 years ago, it was primarily limited to just Southern California.)

Wildfire risk is highly negative for credit quality. The scale of potential liabilities, unpredictable nature of exposures, and frequency of events have materially increased wildfire risk for many utility stakeholders. From a credit standpoint, litigation risk is more problematic than risk of damage to infrastructure because it is difficult to predict or quantify and is so far without sufficient mitigation or containment. Also, wildfire-related litigation payments are typically not recoverable in rates or through other regulatory mechanisms, making them more problematic than physical risk.

Additional wildfire risks to credit quality include:

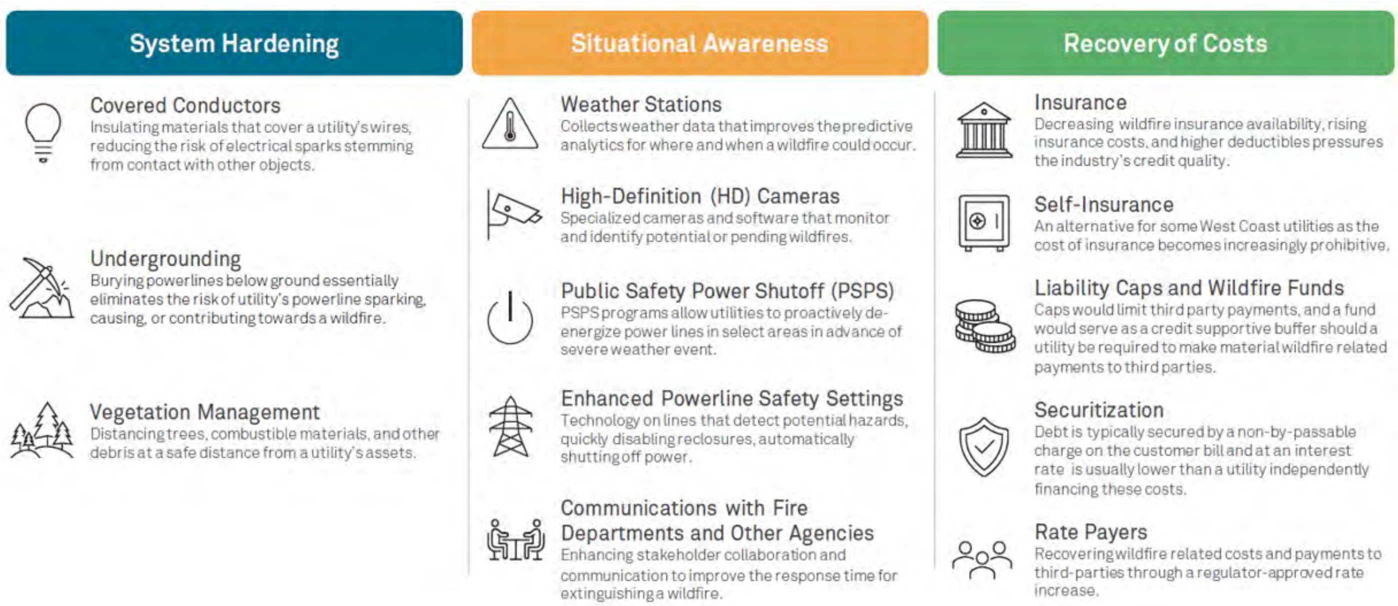
- Insurance is becoming more expensive and less available.
- It only requires a relatively small percentage of damaged or destroyed structures from a wildfire to have a material negative effect on a utility's credit quality.

- The utility industry's relatively high leveraged balance sheets and modest authorized ROEs are not a backstop for wildfire risk.
- Utilities that are impacted by a catastrophic wildfire and material third-party claims typically cannot implement other strategic initiatives.

Mitigation strategies. We expect the industry will develop plans that reduce damages, minimize litigation risk, and expand capabilities for cost recovery from wildfires. We believe the industry will be able to implement much of these strategies over the nearer term because most are not predicated on the development of new technologies or products. That said, because the industry operates in many different service territories and topographies, we expect each utility's mitigation plan will be customized to its unique exposure. Chart 21 represents an array of wildfire mitigation strategies that either have or are being implemented by many utilities across North America.

Chart 21

North American regulated utilities' wildfire mitigation efforts



Source: S&P Global Ratings.

Data centers will likely deliver a return to electricity sales growth. We expect electricity sales will increase at a CAGR of about 1.1%. This reflects our view that systematic and careful planning across the investor-owned utility sector will likely limit its realistic capability to grow at a substantially faster pace. In general, the expansion of utility infrastructure assets is a long-term planning process that requires permitting, siting, and regulatory approvals.

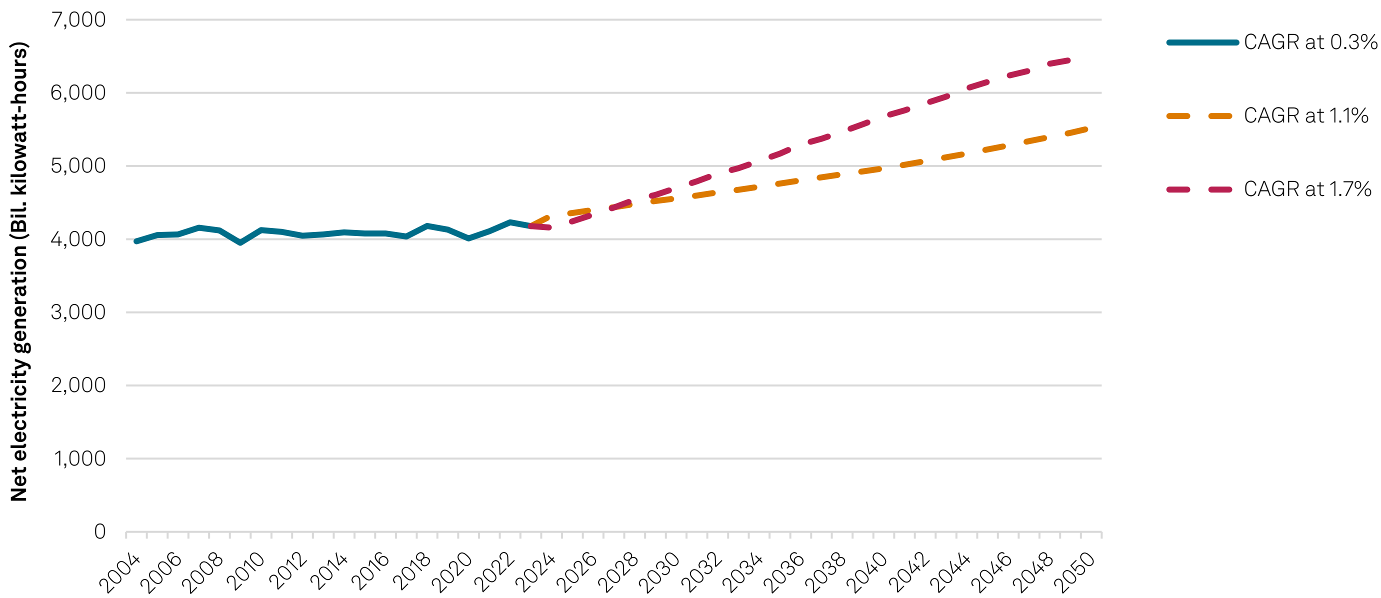
However, even a 1% CAGR for electricity sales will likely prove transformative for the utility industry, which has experienced flat sales growth over the past two decades. In particular, the growing number of data centers will allow the industry to spread its fixed costs over a wider base. We anticipate this will provide some cushion for the industry to effectively manage regulatory risk and maintain credit quality without necessarily requiring that every rate case order is highly supportive of credit quality.

We also expect electric utilities' sales CAGR will be maintained over the longer term (see chart 22), which will support the industry's long-term credit quality. We expect growth in data center numbers will support most of the industry's growth through 2030. In the following decade, increased onshoring of manufacturing and wider spread adoption of electric vehicles will also support growth.

Chart 22

Growth will be transformative for utilities used to stagnation

Electricity demand: U.S. regulated electric utilities



Data as of June 2024. CAGR—Compound annual growth rate. Sources: U.S. Energy Information Administration (historical and 1.1% CAGR) and S&P Global Commodity Insights (1.7% CAGR).

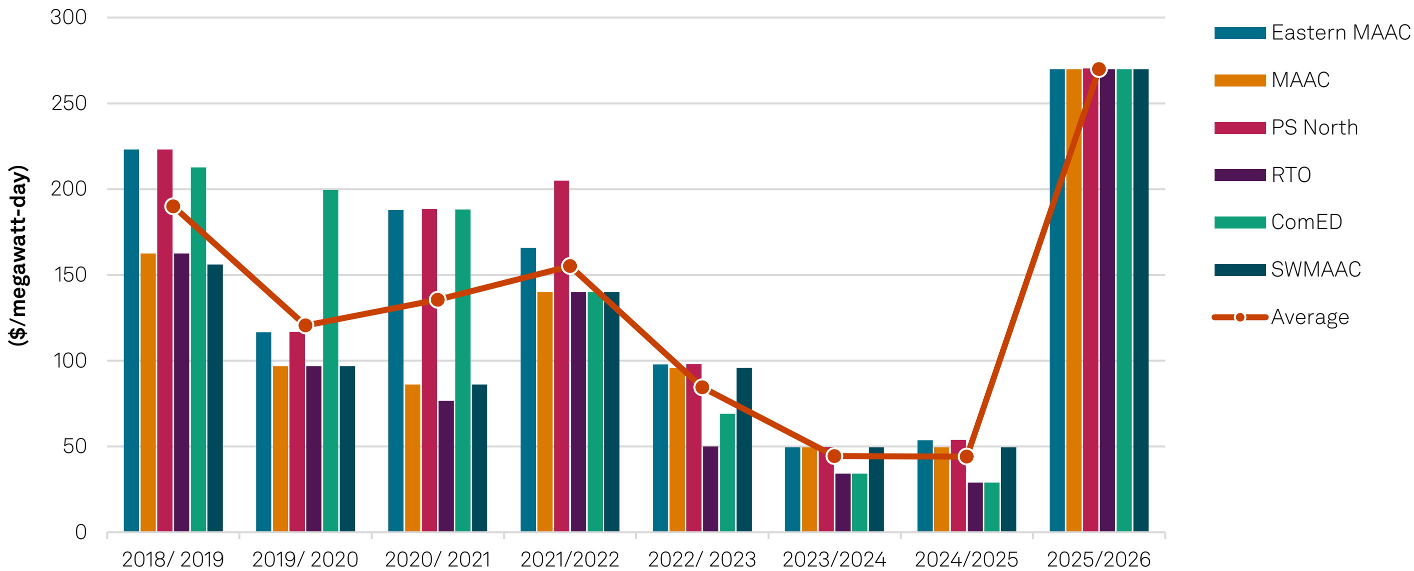
Data center credit risks. The industry must structure rates and contracts to ensure that the new data center customers are paying their share of electricity costs. Meeting the demands of relatively few, but very large, data center customers will require significant capital spending and infrastructure investments. If utilities assign a significant portion of data center-related infrastructure costs to existing residential customers, customer bills would increase. This, in turn, pressures regulators to limit rate case increases, which can negatively affect the industry's ability to effectively manage regulatory risk.

Therefore, we expect the increased capital spending needed to accommodate data center growth will be primarily recovered from data center customers over decades. Such a plan comes with risks. For example, a technological breakthrough that reduces or eliminates the need for data centers could shift the recovery of these long-term infrastructure investments onto residential customers.

Capacity prices. Pennsylvania-New Jersey-Maryland (PJM) Interconnection capacity prices materially increased during its latest capacity auction (see chart 23). These higher prices are directly passed onto customers, significantly increasing the electric utility bill. If these higher prices persist, it will likely result in higher customer complaints, pressuring regulators to limit increases to other areas of the customer bill that could potentially pressure a utility's ability to effectively manage regulatory risk.

Chart 23

PJM capacity auction results



Source: PJM website.

U.S. Environmental Protection Agency (EPA). In 2024 the EPA released final rules aimed at reducing pollution from fossil fuel-fired power plants, which included carbon pollution standards and effluent limitation guidelines and standards for coal-fired power plants. These rules would have increased costs for utilities, specifically regarding the requirement to install carbon capture and sequestration or storage technology on coal-fired power plants intending to operate beyond 2039.

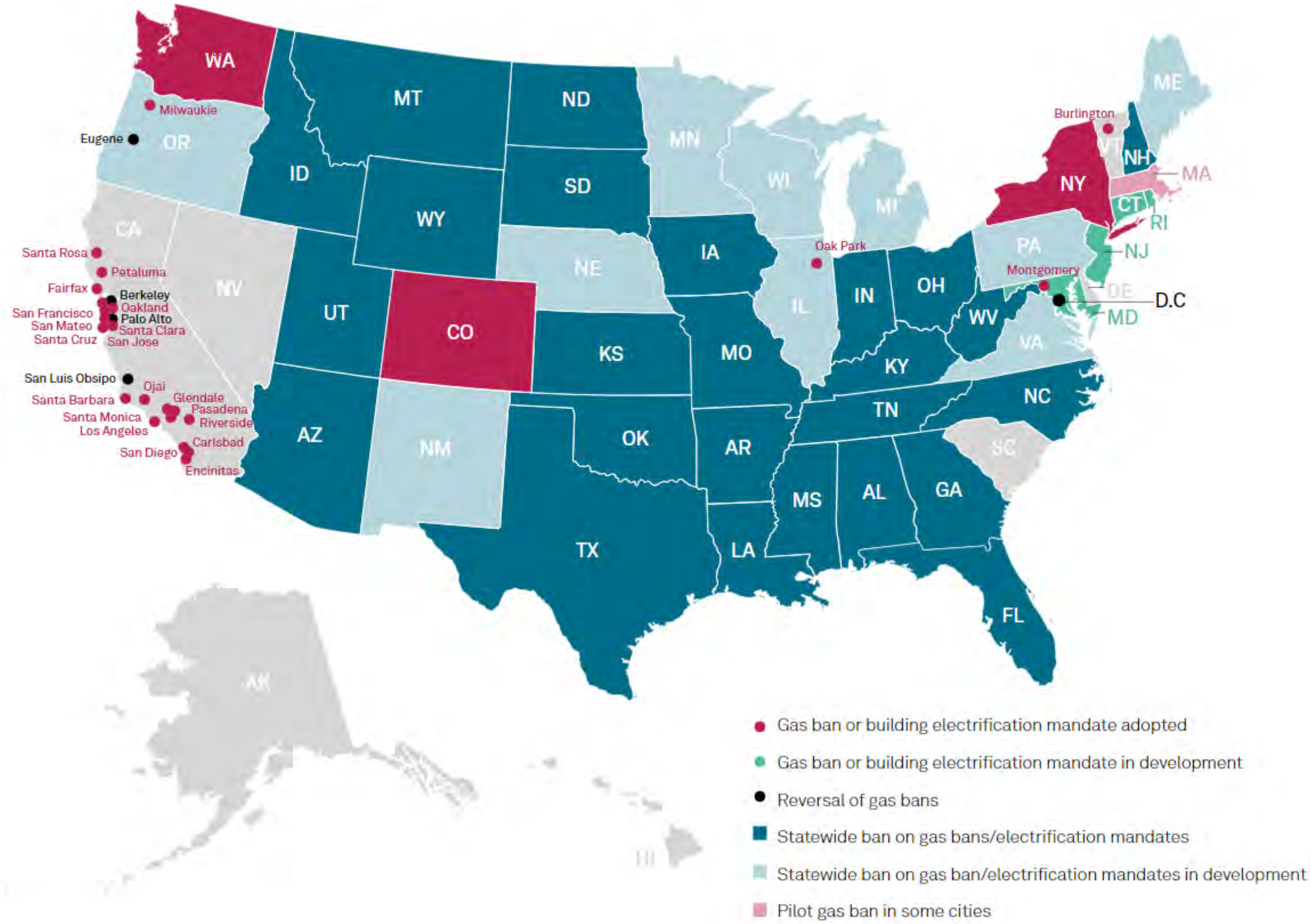
However, we note that the incoming U.S. presidential administration and Republican majority in congress could modify or eliminate these rules. We will monitor executive, legislative, or legal actions that could impact the industry's credit quality.

Full electrification. We expect the longer-term credit quality for some natural gas local distribution companies (LDC) will become increasingly challenging, especially for utilities that operate in warmer climates or whose cities or states have banned new gas connections, severely limiting the growth of natural gas LDCs (see chart 24). We expect this trend will also gradually persist through the passage of local city and town building codes that limit carbon and other emissions.

Offsetting some of this risk is that a majority of states have imposed a ban on the ban of new gas connections. Furthermore, gas LDCs are attempting to reduce their environmental risks by decreasing their carbon footprint through investing in renewable natural gas, blending hydrogen, and initiating various hydrogen infrastructure projects.

Chart 24

Gas bans and electrification mandates



Data as of April 26, 2024. *Municipalities shown on map are a subset of municipalities in the U.S. that have gas ban policies or electric reach codes in place. §Colorado and Burlington mandates target emissions requirements set out in respective laws or regulations. Source: S&P Global Commodity Insights.

Cybersecurity. While cybersecurity breaches against infrastructure assets have been relatively low, we believe the threat of cyberattacks remains high. The 2024 cybersecurity breach against American Water Works Co. Inc. underscores the risks. But the sector has heavily invested to limit this risk. We believe the sector's ongoing vigilance in this area is critical to maintaining credit quality.

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CLIMATE & ENVIRONMENT

Power-hungry AI data centers are raising electric bills and blackout risk

A Santa Clara neighborhood sits in the shadow of a large data center. There are more than 50 data centers in the city of Santa Clara that consume 60% of the power from the municipal utility called Silicon Valley Power. (Paul Kuroda / For The Times)

By Melody Petersen
Staff Writer | 𝕏 Follow

Aug. 12, 2024 3 AM PT

Near the Salton Sea, a company plans to build a data center to support artificial intelligence that would cover land the size of 15 football fields and require power that could support 425,000 homes.

In Santa Clara — the heart of Silicon Valley — electric rates are rising as the municipal utility spends heavily on transmission lines and other infrastructure to accommodate the voracious power demand from more than 50 data centers, which now consume 60% of the city's electricity.

And earlier this year, Pacific Gas & Electric told investors that its customers have proposed more than two dozen data centers, requiring 3.5 gigawatts of power — the output of three new nuclear reactors.

Vantage Data Center in Santa Clara is equipped with its own electrical substations. (Paul Kuroda / For The Times)

While the benefits and risks of AI continue to be debated, one thing is clear: The technology is rapacious for power. Experts warn that the frenzy of data center construction could delay California's transition away from fossil fuels and raise electric bills for everyone else. The data centers' insatiable appetite for electricity, they say, also increases the risk of blackouts.

Even now, California is at the verge of not having enough power. An analysis of public data by the nonprofit GridClue ranks California 49th of the 50 states in resilience — or the ability to avoid blackouts by having more electricity available than homes and businesses need at peak hours.

"California is working itself into a precarious position," said Thomas Popik, president of the Foundation for Resilient Societies, which created GridClue to educate the public on threats posed by increasing power use.

The state has already extended the lives of Pacific Gas & Electric Co.'s Diablo Canyon nuclear plant as well as some natural gas-fueled plants in an attempt to avoid blackouts on sweltering days when power use surges.

Worried that California could no longer predict its need for power because of fast-rising use, an association of locally run electricity providers called on state officials in May to immediately analyze how quickly demand was increasing.

The California Community Choice Assn. sent its letter to the state energy commission after officials had to revise their annual forecast of power demand upward because of skyrocketing use by Santa Clara's dozens of data centers.

A large NTT data center rises in a Santa Clara neighborhood. (Paul Kuroda / For The Times)

The facilities, giant warehouses of computer servers, have long been big power users. They support all that Americans do on the internet — from online shopping to streaming Netflix to watching influencers on TikTok.

But the specialized chips required for generative AI use far more electricity — and water — than those that support the typical internet search because they are designed to read through vast amounts of data.

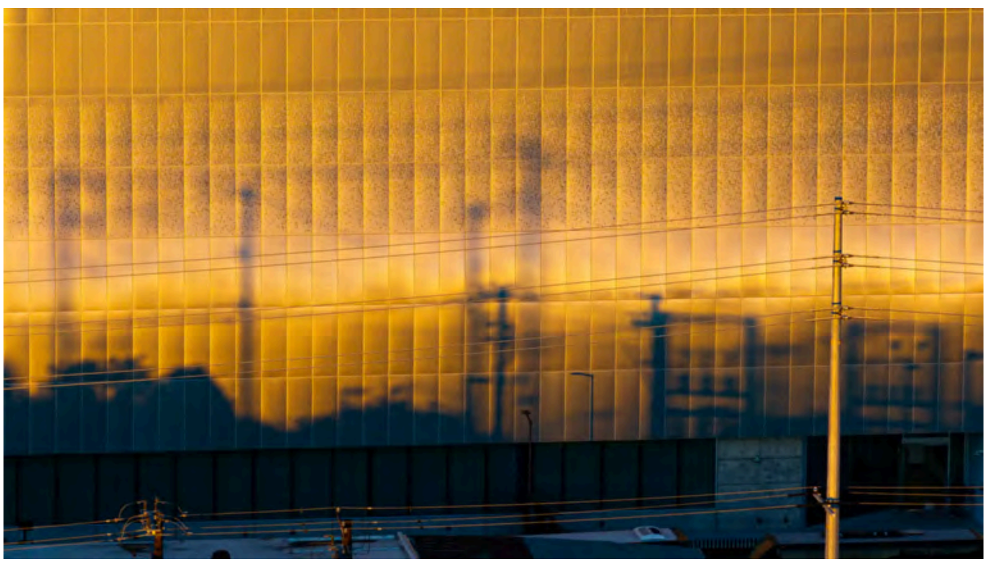
A ChatGPT-powered search, according to the International Energy Agency, consumes 10 times the power as a search on Google without AI.

And because those new chips generate so much heat, more power and water is required to keep them cool.

"I'm just surprised that the state isn't tracking this, with so much attention on power and water use here in California," said Shaolei Ren, associate professor of electrical and computer engineering at UC Riverside.

Ren and his colleagues calculated that the global use of AI could require as much fresh water in 2027 as that now used by four to six countries the size of Denmark.

Driving the data center construction is money. Today's stock market rewards companies that say they are investing in AI. Electric utilities profit as power use rises. And local governments benefit from the property taxes paid by data centers.



Transmission lines are reflected on the side of the NTT data center in Santa Clara. (Paul Kuroda / For The Times)

Silicon Valley is the world's epicenter of AI, with some of the biggest developers headquartered there, including Alphabet, Apple and Meta. OpenAI, the creator of ChatGPT, is based in San Francisco. Nvidia, the maker of chips needed for AI, operates from Santa Clara.

The big tech companies leading in AI, which also include Microsoft and Amazon, are spending billions to build new data centers around the world. They are also paying to rent space for their servers in so-called co-location data centers built by other companies.

In a Chicago suburb, a developer recently bought 55 homes so they could be razed to build a sprawling data center campus.

Energy officials in northern Virginia, which has more data centers than any other region in the world, have proposed a transmission line to shore up the grid that would depend on coal plants that had been expected to be shuttered.

In Oregon, Google and the city of The Dalles fought for 13 months to prevent the Oregonian from getting records of how much water the company's data centers were consuming. The newspaper won the court case, learning the facilities drank up 29% of the city's water.

By 2030, data centers could account for as much as 11% of U.S. power demand — up from 3% now, according to analysts at Goldman Sachs.

"We must demand more efficient data centers or else their continued growth will place an unsustainable strain on energy resources, impact new home building, and increase both carbon emissions and California residents' cost of electricity," wrote Charles Giancarlo, chief executive of the Santa Clara IT firm Pure Storage.

Santa Clara a top market for data centers

Boys ride their bikes on Main Street near a large data center in Santa Clara. (Paul Kuroda / For The Times)

California has more than 270 data centers, with the biggest concentration in Santa Clara. The city is an attractive location because its electric rates are 40% lower than those charged by PG&E.

But the lower rates come with a higher cost to the climate. The city's utility, Silicon Valley Power, emits more greenhouse gas than the average California electric utility because 23% of its power for commercial customers comes from gas-fired plants. Another 35% is purchased on the open market where the electricity's origin can't be traced.

The utility also gives data centers and other big industrial customers a discount on electric rates.

While Santa Clara households pay more for each kilowatt hour beyond a certain threshold, the rate for data centers declines as they use more power.

The city receives millions of dollars of property taxes from the data centers. And 5% of the utility's revenue goes to the city's general fund, where it pays for services such as road maintenance and police.

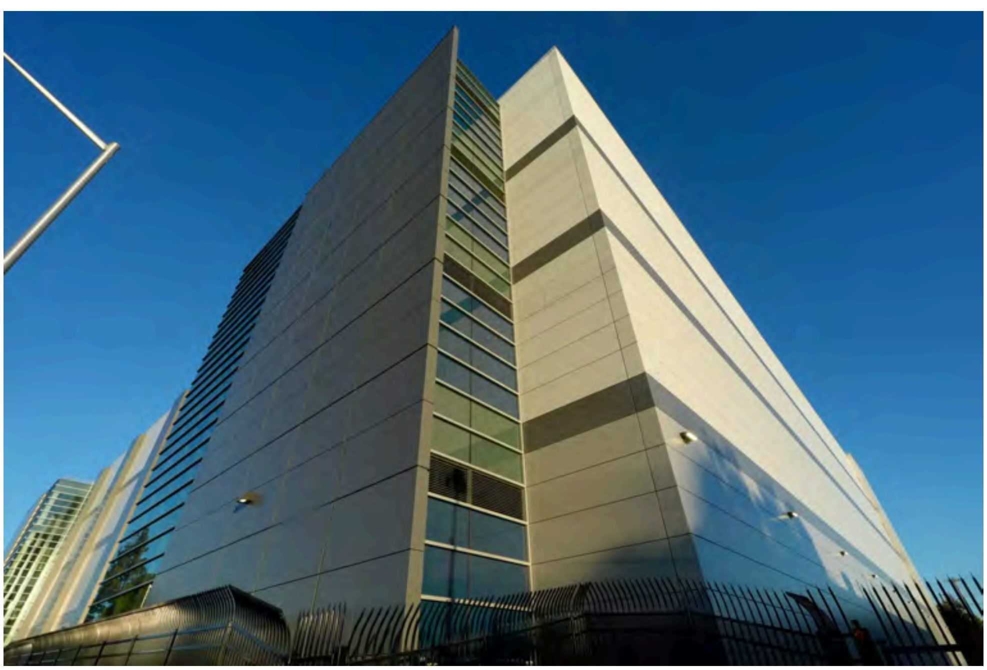
An analysis last year by the Silicon Valley Voice newspaper questioned the lower rates data centers pay compared with residents.

"What impetus do Santa Clarans have to foot the bill for these environmentally unfriendly behemoth buildings?" wrote managing editor Erika Towne.

In October, Manuel Pineda, the utility's top official, told the City Council that his team was working to double power delivery over the next 10 years. "We prioritize growth as a strategic opportunity," he said.

He said usage by data centers was continuing to escalate, but the utility was nearing its power limit. He said 13 new data centers were under construction and 12 more were moving forward with plans.

"We cannot currently serve all data centers that would like to be in Santa Clara," he said.



Dozens of data centers have been built for artificial intelligence and the internet in Santa Clara. (Paul Kuroda / For The Times)

To accommodate increasing power use, the city is now spending heavily on transmission lines, substations and other infrastructure. At the same time, electric rates are rising. Rates had been increasing by 2% to 3% a year, but they jumped by 8% in January 2023, another 5% in July 2023 and 10% last January.

Pineda told The Times that it wasn't just the new infrastructure that pushed rates up. The biggest factor, he said, was a spike in natural gas prices in 2022, which increased power costs.

He said residential customers pay higher rates because the distribution system to homes requires more poles, wires and transformers than the system serving data centers, which increases maintenance costs.

Pineda said the city's decisions to approve new data centers "are generally based on land use factors, not on revenue generation."

Loretta Lynch, former chair of the state's public utilities commission, noted that big commercial customers such as data centers pay lower rates for electricity across the state. That means when transmission lines and other infrastructure must be built to handle the increasing power needs, residential customers pick up more of the bill.

"Why aren't data centers paying their fair share for infrastructure? That's my question," she said.

PG&E eyes profits from boom

The grid's limited capacity has not stopped PG&E from wooing companies that want to build data centers.

"I think we will definitely be one of the big ancillary winners of the demand growth for data centers," Patricia Poppe, PG&E's chief executive, told Wall Street analysts on an April conference call.

Poppe said she recently invited the company's tech customers to an event at a San José substation.

"When I got there, I was pleasantly surprised to see AWS, Microsoft, Apple, Google, Equinix, Cisco, Western Digital Semiconductors, Tesla, all in attendance. These are our customers that we serve who want us to serve more," she said on the call. "They were very clear: they would build … if we can provide."

In June, PG&E revealed it had received 26 applications for new data centers, including three that need at least 500 megawatts of power, 24 hours a day. In all, the proposed data centers would use 3.5 gigawatts. That amount of power could support nearly 5 million homes, based on the average usage of a California household of 6,174 kilowatts a year.

In the June presentation, PG&E said the new data centers would require it to spend billions of dollars on new infrastructure.

Already PG&E can't keep up with connecting customers to the grid. It has fallen so far behind on connecting new housing developments that last year legislators passed a law to try to shorten the delays. At that time, the company told Politico that the delays stemmed from rising electricity demand, including from data centers.

In a statement to The Times, PG&E said its system was "ready for data centers."

The company said its analysis showed that adding the data centers would not increase bills for other customers.

Most of the year, excluding extreme hot weather, its grid "is only 45% utilized on average," the company said.

"Data centers' baseload will enable us to utilize more of this percentage and deliver more per customer dollar," the company said. "For every 1,000 MW load from data centers we anticipate our customers could expect 1-2% saving on their monthly electricity bill."

The company added that it was "developing tools to ensure that every customer can cost-effectively connect new loads to the system with minimal delay."

Lynch questioned the company's analysis that adding data centers could reduce bills for other customers. She pointed out that utilities earn profits by investing in new infrastructure. That's because they get to recover that cost — plus an annual rate of return — through rates billed to all customers.

"The more they spend, the more they make," she said.

In the desert, cheap land and green energy

A geothermal plant viewed from across the Salton Sea in December 2022. (Gina Ferazzi / Los Angeles Times)

The power and land constraints in Santa Clara and other cities have data center developers looking for new frontiers.

"On the edge of the Southern California desert in Imperial County sits an abundance of land," begins the sales brochure for the data center that a company called CalEthos is building near the south shore of the Salton Sea.

Electricity for the data center's servers would come from the geothermal and solar plants built near the site in an area that has become known as Lithium Valley.

The company is negotiating to purchase as much as 500 megawatts of power, the brochure said.

Water for the project would come from the state's much fought over allotment from the Colorado River.

Imperial County is one of California's poorest counties. More than 80% of its population are Latino. Many residents are farmworkers.

Executives from Tustin-based CalEthos told The Times that by using power from the nearby geothermal plants it would help the local community.

"By creating demand for local energy, CalEthos will help accelerate the development of Lithium Valley and its associated economic benefits," Joel Stone, the company's president, wrote in an email.

"We recognize the importance of responsible energy and water use in California," Stone said. "Our data centers will be designed to be as efficient as possible."

For example, Stone said that in order to minimize water use, CalEthos plans a cooling system where water is recirculated and "requires minimal replenishment due to evaporation."

Already, a local community group, Comite Civico del Valle, has raised concerns about the environmental and health risks of one of the nearby geothermal plants that plans to produce lithium from the brine brought up in the energy production process.

One of the group's concerns about the geothermal plant is that its water use will leave less to replenish the Salton Sea. The lake has been decreasing in size, creating a larger dry shoreline that is laden with bacteria and chemicals left from decades of agricultural runoff. Scientists have tied the high rate of childhood asthma in the area to dust from the shrinking lake's shores.

James Blair, associate professor of geography and anthropology at Cal Poly Pomona, questioned whether the area was the right place for a mammoth data center.

"Data centers drain massive volumes of energy and water for chillers and cooling towers to prevent servers from overheating," he said.

Blair said that while the company can tell customers its data center is supported by environmentally friendly solar and geothermal power, it will take that renewable energy away from the rest of California's grid, making it harder for the state to meet its climate goals.

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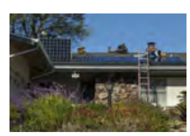

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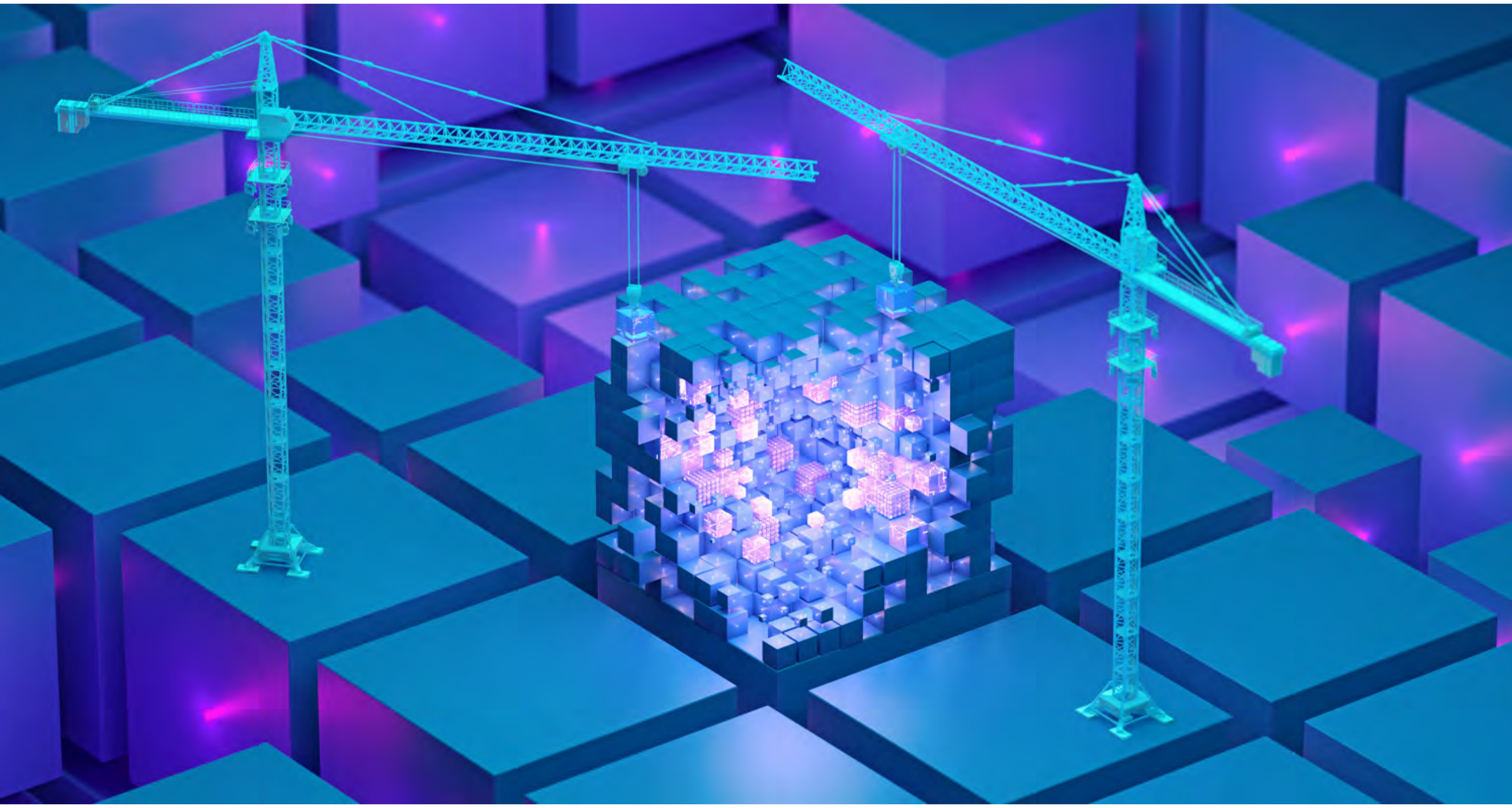
McKinsey Quarterly

Technology, Media & Telecommunications Practice

The cost of compute: A $7 trillion race to scale data centers

AI is fueling high demand for compute power, spurring companies to invest billions of dollars in infrastructure. But with future demand uncertain, investors will need to make calculated decisions.

This article is a collaborative effort by Jesse Noffsinger, Mark Patel, and Pankaj Sachdeva, with Arjita Bhan, Haley Chang, and Maria Goodpaster, representing views from McKinsey's Technology, Media & Telecommunications Practice.



April 2025

Amid the AI boom, compute power is emerging as one of this decade's most critical resources. In data centers across the globe, millions of servers run 24/7 to process the foundation models and machine learning applications that underpin AI. The hardware, processors, memory, storage, and energy needed to operate these data centers are collectively known as compute power—and there is an unquenchable need for more.

Our research shows that by 2030, data centers are projected to require $6.7 trillion worldwide to keep pace with the demand for compute power. Data centers equipped to handle AI processing loads are projected to require $5.2 trillion in capital expenditures, while those powering traditional IT applications are projected to require $1.5 trillion in capital expenditures (see sidebar "What about non-AI workloads?"). Overall, that's nearly *$7 trillion* in capital outlays needed by 2030—a staggering number by any measure.[1]

What about non-AI workloads?

While AI workloads dominate the conversation, non-AI processing loads remain a significant portion of data center activity. These include traditional enterprise IT tasks such as web hosting, enterprise resource planning systems, email, and file storage. Non-AI loads are less compute-intensive and can operate efficiently on central processing units rather than the specialized graphics processing units or AI accelerators that AI workloads require. They also tend to have more predictable usage patterns and lower power densities, which allow for less demanding cooling and energy requirements. As a result, data centers focused on non-AI processing typically have different infrastructure needs, capital intensity, and operational considerations compared with those optimized for AI.

To meet this demand, companies across the compute power value chain must strike a balance between deploying capital quickly and doing so prudently. To improve the odds that their data center investments will provide strong returns, companies can tackle projects in stages, assessing ROI at each step. Still, a lack of clarity about future demand makes precise investment calculations difficult.

The compute power value chain is complex—from the real estate developers that build data centers to the utilities that power them, to the semiconductor firms that produce chips to the cloud service hyperscalers that host trillions of terabytes of data. Leaders across this value chain know that they must invest in compute power to accelerate AI growth. But their challenge

[1] McKinsey Data Center Demand Model, McKinsey Data Center Capex TAM Model, and expert interviews.

is formidable: deciding how much capital to allocate to which projects, all while remaining uncertain of how AI's future growth and development will impact compute power demand. Will hyperscalers continue shouldering the cost burden, or will enterprises, governments, and financial institutions step in with new financing models? Will demand for data centers rise amid a continued surge in AI usage, or will it fall as technological advances make AI less compute-heavy?

One thing is certain: The stakes are high. Overinvesting in data center infrastructure risks stranding assets, while underinvesting means falling behind. This article, based on McKinsey research and analysis, provides companies across the compute power value chain with an overview of the investment landscape for the next five years. Despite the rigor behind these forecasts, we acknowledge that AI is a radically evolving space. Our analysis is built on thoroughly researched hypotheses, but there are critical uncertainties that cannot yet be quantified.

Predicting the compute power demand curve

To decide how much to invest in compute power, companies should first accurately forecast future demand—a challenging task given that the AI sector is shifting so rapidly. Our research shows that global demand for data center capacity could almost triple by 2030, with about 70 percent of that demand coming from AI workloads (Exhibit 1). However, this projection hinges on two key uncertainties:

— *AI use cases*. The value in AI lies at the application layer—how enterprises turn AI into real business impact. If companies fail to create meaningful value from AI, demand for compute power could fall short of expectations. Conversely, transformative AI applications could fuel even greater demand than current projections suggest.

— *Rapid innovation cycles and disruptions*. Continuous advancements in AI technologies, such as processors, large language model (LLM) architectures, and power consumption, could significantly enhance efficiency. For instance, in February 2025, Chinese LLM player DeepSeek reported that its V3 model achieved substantial improvements in training and reasoning efficiency, notably reducing training costs by approximately 18 times and inferencing costs by about 36 times, compared with GPT-4o.[2] However, preliminary analysis suggests that these types of efficiency gains will likely be offset by increased experimentation and training across the broader AI market. As a result, efficiency gains may not substantially impact overall compute power demand over the long term.[3]

AI demand alone will require $5.2 trillion in investment

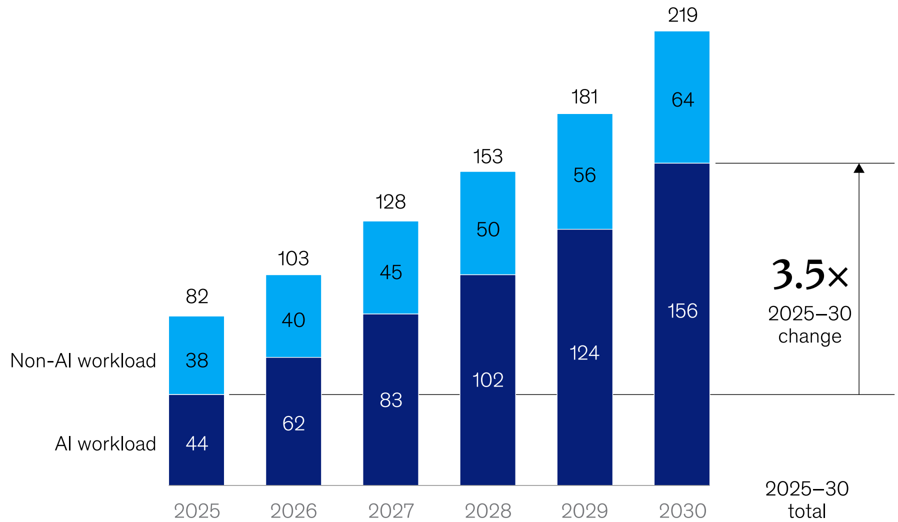
We calculate that companies across the compute power value chain will need to invest *$5.2 trillion into data centers by 2030* to meet worldwide demand for AI alone. We based this figure on extensive analysis and key assumptions, including a projected 156 gigawatts (GW) of AI-

[2] Manish Singh, "DeepSeek 'punctures' AI leaders' spending plans, and what analysts are saying," TechCrunch, January 27, 2025; Wayne Williams, "OpenAI spent $80M to $100M training GPT-4; Chinese firm claims it trained its rival AI model for $3 million using just 2,000 GPUs," TechRadar, December 2, 2024; "Independent analysis of AI models and API providers," Artificial Analysis, January 27, 2025.
[3] This aligns with the concept of Jevons Paradox, which posits that improvements in efficiency can lead to increased overall demand. In the context of AI, more efficient and accessible computing resources could spur greater adoption and utilization, potentially offsetting the anticipated reductions in compute demand.

Exhibit 1

Both AI and non-AI workloads will be key drivers of global data center capacity demand growth through 2030.

Estimated global data center capacity demand, 'continued momentum' scenario, gigawatts



	2025	2026	2027	2028	2029	2030	2025–30 total
Incremental AI capacity added per year, gigawatts	13	18	21	19	22	31	124

Note: Figures may not sum to totals, because of rounding.
Source: McKinsey Data Center Demand Model; Gartner reports; IDC reports; Nvidia capital markets reports

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related data center capacity demand by 2030, with 125 incremental GW added between 2025 and 2030. This $5.2 trillion figure reflects the sheer scale of investment required to meet the growing demand for AI compute power—a significant capital commitment that underscores the magnitude of the challenge ahead (see sidebar "The scale of investment").

Amid the uncertainty about future needs for compute power, we created three investment scenarios ranging from constrained to accelerated demand (Exhibit 2). In the first of our three scenarios, growth accelerates significantly and 205 incremental GW of AI-related data center capacity is added between 2025 and 2030. This would require an estimated $7.9 trillion in capital expenditures. The second scenario is the one we use in this article: Demand grows, but not as much as in the first scenario, and the expected capital expenditure is $5.2 trillion. In our third scenario, in which demand is more constrained, with 78 incremental GW added in the next five years, the total capital expenditure is $3.7 trillion (see sidebar "Methodology ").

The scale of investment

To put the trillion-dollar size of investment needed by 2030 into perspective, consider these unrelated statistics that illustrate the sheer scale of capital needed:

— *Labor*. $500 billion in labor costs is roughly equivalent to 12 billion labor hours (six million people working full time for an entire year).[1]

— *Fiber*. $150 billion worth of fiber is equivalent to installing three million miles of fiber-optic cables—enough to circle the Earth 120 times.[2]

— *Power generation*. $300 billion worth of power generation is equivalent to adding 150 to 200 gigawatts of gas, which would be enough to power 150 million homes for a year—more than the total number of households in the United States.[3]

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[1] Estimated conservatively, using a high-end hourly wage of $40 (for roles ranging from construction workers to data center technicians), assuming a standard 40-hour workweek and 52 weeks per year. "Occupational employment and wage statistics survey by occupation–May 2024," US Bureau of Labor Statistics news release, April 2, 2025.
[2] Estimated based on an average of $50,000 as the per-mile aerial installation cost of fiber-optic cables. Jonathan Kim, "Fiber optic network construction: Process and build costs," Dgtl Infra, January 15, 2024.
[3] Estimated assuming full utilization and average US household electricity consumption of 10,500 kilowatt-hours per year. Based on data from the US Energy Information Administration.

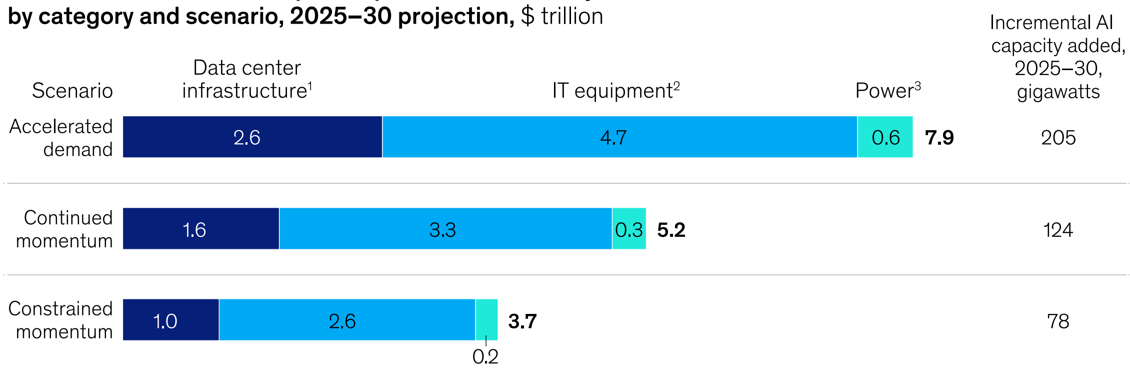
Methodology

Capital expenditure estimates in this article are derived from McKinsey's proprietary data center demand model, which projects data center capacity under multiple scenarios shaped by factors such as semiconductor supply constraints, enterprise AI adoption, efficiency improvements, and regulatory challenges. Investment requirements were calculated by translating demand projections for gigawatt capacity into capital expenditures across major cost categories, including power (for example, generation, transmission), data center infrastructure (for example, electrical, mechanical, site, shell), and IT equipment (for example, AI accelerators, networking, storage).

Exhibit 2

Capital investments to support AI-related data center capacity demand could range from about $3 trillion to $8 trillion by 2030.

Global data center total capital expenditures driven by AI, by category and scenario, 2025–30 projection, $ trillion



Note: Figures may not sum to totals, because of rounding.
[1]Excludes IT services and software (eg, operating system, data center infrastructure management), since they require relatively low capex compared with other components.
[2]Includes server, storage, and network infrastructure. IT capex also accounts for replacing AI accelerators every 4 years.
[3]Assumes $2.2 billion–$3.2 billion/gigawatt (including power generation and transmission cost) to account for a range of power generation scenarios (eg, fully powered by gas, a combination of gas power and storage, and solar) and regional cost differences. Distribution cost is neglected, as most AI centers are expected to be >50 megawatt scale and connected to a transmission grid.
Source: McKinsey Data Center Capex TAM Model; McKinsey Data Center Demand Model

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In any scenario, these are staggering investment numbers. They are fueled by several factors:

— *Mass adoption of gen AI*. The foundation models that underpin gen AI require significant compute power resources to train and operate. Both training and inference workloads are contributing to infrastructure growth, with inference expected to become the dominant workload by 2030.

— *Enterprise integration*. Deploying AI-powered applications across industries—from automotive to financial services—demands massive cloud computing power. As use cases grow, AI applications will grow more sophisticated, integrating specialized foundation models tailored to specific domains.

— *Competitive infrastructure race*. Hyperscalers and enterprises are racing to build proprietary AI capacity to gain competitive advantage, which is fueling the construction of more and more data centers. These “builders” (as further described below) hope to gain competitive advantage by achieving scale, optimizing across data center tech stacks, and ultimately driving down the cost of compute.

— *Geopolitical priorities*. Governments are investing heavily in AI infrastructure to enhance security, economic leadership, and technological independence.

Where is the investment going?

To qualify our $5.2 trillion investment forecast for AI infrastructure, it's important to note that our analysis likely undercounts the total capital investment needed, as our estimate quantifies capital investment for only three out of five compute power investor archetypes—builders, energizers, and technology developers and designers—that directly finance the infrastructure and foundational technologies necessary for AI growth (see sidebar "Five types of data center investors"). Approximately 15 percent ($0.8 trillion) of investment will flow to builders for land, materials, and site development. Another 25 percent ($1.3 trillion) will be allocated to energizers for power generation and transmission, cooling, and electrical equipment. The largest share of investment, 60 percent ($3.1 trillion), will go to technology developers and designers, which produce chips and computing hardware for data centers. The other two investor archetypes, operators, such as hyperscalers and colocation providers, and AI architects, which build AI models and applications, also invest in compute power, particularly in areas such as AI-driven automation and data center software. But quantifying their compute power investment is challenging because it overlaps with their broader R&D spending.

Despite these projected capital requirements, our research shows that current investment levels lag demand. In dozens of client interviews, we found that CEOs are hesitant to invest in compute power capacity at maximum levels because they have limited visibility into future demand. Uncertainty about whether AI adoption will continue its rapid ascent and the fact that infrastructure projects have long lead times make it difficult for companies to make informed investment decisions. Many companies are unsure whether large capital expenditures on AI infrastructure today will produce measurable ROI in the future. So how can business leaders move forward confidently with their investments? As a first step, they can determine where their organizations fall within the compute power ecosystem.

Five archetypes of AI infrastructure investors

Who are the investors behind the multitrillion-dollar race to fund AI compute power? We have identified five key investor archetypes, each navigating distinct challenges and opportunities, and detailed how much they could spend in the next five years.

1. Builders

— *Who they are*: real estate developers, design firms, and construction companies expanding data center capacity

Five types of data center investors

As AI drives a surge in compute power demand, five types[1] of organizations are leading the massive capital investments required to scale data centers:

— *Builders*: real estate developers, design firms, and construction companies that expand and upgrade data centers, such as Turner Construction and AECOM

— *Energizers*: companies that supply the electricity and cooling systems essential for data center operations, including utilities like Duke Energy and Entergy and infrastructure and equipment providers like Schneider Electric and Vertiv

— *Technology developers and designers*: semiconductor companies that develop the chips powering AI workloads, such as NVIDIA and Intel, and computing hardware suppliers such as Foxconn and Flex

— *Operators*: cloud providers and co-location firms that own and run large-scale data centers, such as Amazon Web Services, Google Cloud, and Equinix

— *AI architects*: companies developing AI models and infrastructure, including OpenAI and Anthropic

[1]The companies listed as examples in each archetype category may also span adjacent categories. For instance, hyperscalers in the operators category (Amazon Web Services, Google Cloud) are developing specialized computing hardware and investing in both their own and third-party LLM products—activities that align with the roles of technology developers and designers and AI architects, respectively.

— *AI workload capital expenditure*: $800 billion

— *Non-AI workload capital expenditure*: $100 billion

— *Key investments*: land and material acquisition, skilled labor, site development

Opportunities. Builders that optimize site selection can secure prime locations, reduce construction timelines, and integrate operational feedback early, ensuring faster deployment and higher data center efficiency.

Challenges. Labor shortages could impact technician and construction worker availability, while location constraints could limit site selection options. Meanwhile, increased rack power density could create space and cooling challenges.

Solutions. Forward-thinking builders can find solutions to core challenges, adding certainty to their investment decisions. For example, some are solving the labor shortage issue by adopting modular designs that streamline the construction process, such as off-site construction of large components that can be assembled on-site.

2. Energizers

— *Who they are*: utilities, energy providers, cooling/electrical equipment manufacturers, and telecom operators building the power and connectivity infrastructure for AI data centers[4]

— *AI workload capital expenditure*: $1.3 trillion

— *Non-AI workload capital expenditure*: $200 billion

— *Key investments*: power generation (plants, transmission lines), cooling solutions (air cooling, direct-to-chip liquid cooling, immersion cooling), electrical infrastructure (transformers, generators), network connectivity (fiber, cable)

Opportunities. Energizers that scale power infrastructure and innovate in sustainable energy solutions will be best positioned to benefit from hyperscalers' growing energy demands.

Challenges. Powering data centers could stall due to existing grid weaknesses and solving heat management challenges from rising processor densities remains an obstacle. Energizers also face clean-energy transition requirements and lengthy grid connection approval processes.

Solutions. With over $1 trillion in investment at stake, energizers are finding ways to deliver reliable power while driving ROI. They are making substantial investments in emerging power-generation technologies—including nuclear, geothermal, carbon capture and storage, and long-duration energy storage. They are also doubling down on efforts to bring as much capacity online as quickly as possible across both renewable sources and traditional energy infrastructure, such as gas and fossil fuels. What is changing now is the sheer scale of that demand, which brings a new urgency to build power capacity at unprecedented speed. As demand—especially for clean energy—surges, power generation is expected to grow rapidly, with renewables projected to account for approximately 45 to 50 percent of the energy mix by 2030, up from about a third today.[5]

3. Technology developers and designers

— *Who they are*: semiconductor firms and IT suppliers producing chips and computing hardware for data centers

— *AI workload capital expenditure*: $3.1 trillion

— *Non-AI workload capital expenditure*: $1.1 trillion

[4] For more on how utility and energy providers are investing in AI infrastructure, see "How data centers and the energy sector can sate AI's hunger for power," McKinsey, September 17, 2024; for more on how telecom operators are investing in AI infrastructure, see "AI infrastructure: A new growth avenue for telco operators," McKinsey, February 28, 2025.
[5] "Global Energy Perspective," McKinsey, September 17, 2024.

— *Key investments*: GPUs, CPUs, memory, servers, and rack hardware

Opportunities. Technology developers and designers that invest in scalable, future-ready technologies supported by clear demand visibility could gain a competitive edge in AI computing.

Challenges. A small number of semiconductor firms control the market supply, stifling competition. Capacity building remains insufficient to meet current demand, while at the same time, shifts in AI model training methods and workloads make it difficult to predict future demand for specific chips.

Solutions. Technology developers and designers have the most to gain in the compute power race because they are the ones providing the processors and hardware that do the actual computing. Demand for their products is currently high, but their investment needs are also the greatest—more than $3 trillion over the next five years. A small number of semiconductor firms have a disproportionate influence on industry supply, making them potential chokepoints in compute power growth. Technology developers and designers can mitigate this risk by expanding fabrication capacity and diversifying supply chains to prevent bottlenecks.

4. Operators

— *Who they are*: hyperscalers, colocation providers, GPU-as-a-service platforms, and enterprises optimizing their computing resources by improving server utilization and efficiency

— *AI workload capital expenditure*: not included in this analysis

— *Non-AI workload capital expenditure*: not included in this analysis

— *Key investments*: data center software, AI-driven automation, custom silicon

Opportunities. Operators that scale efficiently while balancing ROI, performance, and energy use can drive long-term industry leadership.

Challenges. Immature AI-hosted applications can obscure long-term ROI calculations. Inefficiencies in data center operations are driving up costs, but uncertainty in AI demand continues to disrupt long-term infrastructure planning and procurement decisions.

Solutions. While data centers today operate at high-efficiency levels, the rapid pace of AI innovation will require operators to optimize both energy consumption and workload management. Some operators are improving energy efficiency in their data centers by investing in more effective cooling solutions and increasing rack stackability to reduce space requirements without sacrificing processing power, for example. Others are investing in AI model development itself to create architectures that need less compute power to be trained and operated.

5. AI architects

- *Who they are*: AI model developers, foundation model providers, and enterprises building proprietary AI capabilities

- *AI workload capital expenditure*: not included in this analysis

- *Non-AI workload capital expenditure*: not included in this analysis

- *Key investments*: model training and inference infrastructure, algorithm research

Opportunities. AI architects that develop architectures that balance performance with lower compute requirements will lead the next wave of AI adoption. Enterprises investing in proprietary AI capabilities can gain competitiveness by developing specialized models tailored to their needs.

Challenges. AI governance issues, including bias, security, and regulation, add complexity and can slow development. Meanwhile, inference poses a major unpredictable cost component, and enterprises are facing difficulties demonstrating clear ROI from AI investments.

Solutions. The escalating computational demands of large-scale AI models are driving up the costs to train them, particularly regarding inference, or the process where trained AI models apply their learned knowledge to new, unseen data to make predictions or decisions. Models with advanced reasoning capabilities, such as OpenAI's o1, require significantly higher inference costs. For example, it costs six times more for inference on OpenAI's o1 compared with the company's nonreasoning GPT-4o. To bring down inference costs, leading AI companies are optimizing their model architectures by using techniques like sparse activations and distillation. These solutions reduce the computational power needed when an AI model generates a response, making operations more efficient.

Critical considerations for AI infrastructure growth

As companies plan their AI infrastructure investments, they will have to navigate a wide range of potential outcomes. In a constrained-demand scenario, AI-related data center capacity could require $3.7 trillion in capital expenditures—limited by supply chain constraints, technological disruptions, and geopolitical uncertainty. These barriers are mitigated, however, in an accelerated-demand scenario, leading to investments as high as $7.9 trillion. Staying on top of the evolving landscape is critical to making informed, strategic investment decisions. Some of the uncertainties investors must consider include:

- *Technological disruptions*. Breakthroughs in model architectures, including efficiency gains in compute utilization, could reduce expected hardware and energy demand.

— *Supply chain constraints*. Labor shortages, supply chain bottlenecks, and regulatory hurdles could delay grid connections, chip availability, and data center expansion—slowing overall AI adoption and innovation. To address supply chain bottlenecks for critical chips, semiconductor companies are investing significant capital to construct new fabrication facilities, but this construction could stall due to regulatory constraints and long lead times from upstream equipment suppliers.

— *Geopolitical tensions*. Fluctuating tariffs and technology export controls could introduce uncertainty in compute power demand, potentially impacting infrastructure investments and AI growth.

The race for competitive advantage

The winners of the AI-driven computing era will be the companies that anticipate compute power demand and invest accordingly. Companies across the compute power value chain that proactively secure critical resources—land, materials, energy capacity, and computing power—could gain a significant competitive edge. To invest with confidence, they can take a three-pronged approach.

First, investors will need to understand demand projections amid uncertainty. Companies should assess AI computing needs early, anticipate potential shifts in demand, and design scalable investment strategies that can adapt as AI models and use cases evolve. Second, investors should find ways to innovate on compute efficiency. To do so, they can prioritize investments in cost- and energy-efficient computing technologies, optimizing performance while managing power consumption and infrastructure costs. Third, they can build supply-side resilience to sustain AI infrastructure growth without overextending capital. This will require investors to secure critical inputs such as energy and chips, optimize site selection, and build flexibility into their supply chains.

Striking the right balance between growth and capital efficiency will be critical. Investing strategically is not just a race to scale data infrastructure—it's a race to shape the future of AI itself.

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The authors wish to thank Andrea Boza Zanatta, Jason Amri, Rishi Gupta, Senem Bilir, and Shraddha Kumar for their contributions to this article.

This article was edited by Kristi Essick, an executive editor in the Bay Area office.