Industrials/Multi-Industry

When AI meets grid: why Elon Musk cares about transformers

Industry Overview

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Equity
Americas
Industrials/Multi-Industry

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Why does Elon Musk care about transformers?

In a recent interview with Lex Fridman, Elon Musk mused on the future impact of artificial intelligence (AI) on the electrical grid. “We have a silicon shortage today, a voltage step-down transformer shortage probably in about a year, and then just electricity shortages in general in about two years.” While Musk’s timeline seems aggressive, our research on AI and electrification trends suggests demand for electricity – and key electrical equipment – is set to accelerate through the end of this decade. Beneficiaries in our coverage include Buy-rated Eaton (ETN), Vertiv (VRT), Aspen Technologies (AZPN), and GE (GE).

Data centers 1-2% of electricity in ‘23, 11+% CAGR

Data centers consume 1-2% of global electricity produced today. A meta-analysis of 46 forecasts suggests this will grow at an 11% CAGR through 2030. However, given the energy intensive nature of AI chips, we see an upward bias to these estimates. For example, Schneider’s Energy Research Management Center forecasts AI-specific electrical demand to grow at a 26-33% CAGR over 2023-28. As a real-world example, NVIDIA’s artificial intelligence server shipments in 2023 will consume a similar amount of electricity as 20mn US homes once installed and running.

The many levels of electrical equipment in data centers

Data centers require multiple levels of electrical equipment for reliability and redundancy. From the utility feed, electricity goes to switch gear, step-down transformers, uninterruptible power supplies (i.e., backup batteries), power distribution units (which further step-down the voltage), remote power panels (which create separate circuits), conduit systems, racks, and finally to servers. For Tier 3 or 4 data centers, there are two separate electrical paths for redundancy. From our conversations with electrical distributors, data centers are taking a disproportionate amount of incremental capacity being added by electrical equipment manufacturers.

Electricity shortages? Maybe not, but more demand likely

In the interview Elon Musk said, “Energy usage right now is, very rough terms, 1/3rd electricity, 1/3rd transportation, and 1/3rd heating. In order for everything to go electric, you need to triple electricity output.” Electric vehicles (EV) comprise 1.6% of US passenger vehicles on the road today. This is forecast to increase to ~15% by 2030, according to Bloomberg NEF. Using US Department of Energy data, we find charging a single EV at home increases the average US household’s electrical consumption by 46%. We think a combination of regulations, tax credits, and replacement cycles will increase the use of electricity for space heating in commercial buildings (e.g., heat pumps).

Refer to important disclosures on page 12 to 16. Analyst Certification on page 11. Price Objective Basis/Risk on page 10. 12645602

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When AI meets the grid

> "We have a silicon shortage today, a voltage step-down transformer shortage probably in about a year, and then just electricity shortages in general in about two years." — Elon Musk on 11/9/23

Data centers use 1-2% of total electricity today…

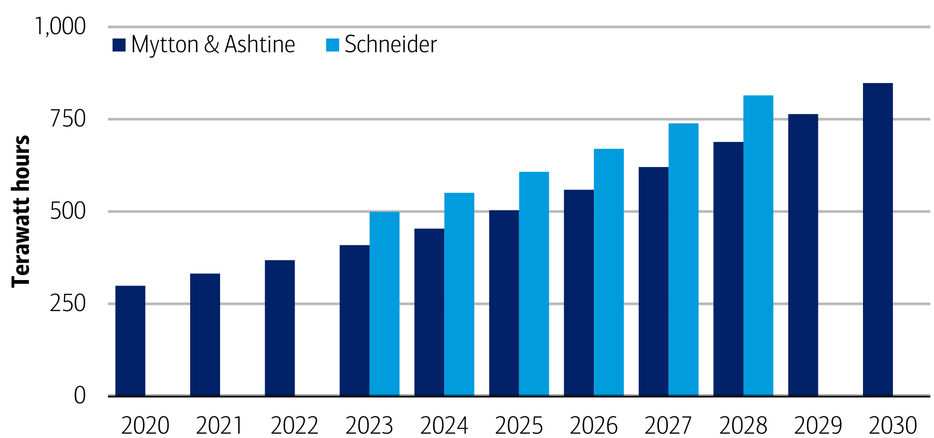
Data centers consume approximately 1-2% of total electricity production today. Estimates range from 240-340 terawatt hours (TWh) in 2022 according to the International Energy Agency, 409 TWh in 2023 according to a meta-analysis[1] of 46 forecasts, and 499 TWh in 2023 per Schneider[2].

…but likely to grow at an 11+% CAGR

Forecasting data center electricity consumption has been a prevalent topic among academics and industry research. Forecast methodologies range from bottom-up (e.g., equipment shipments), top-down (e.g., data consumption), and extrapolation (e.g., energy intensity per chip). The median forecast of a meta-analysis of 46 separate forecast (Mytton & Ashtine) suggest data center energy usage to grow at an 11% CAGR through 2030. We also show Schneider's forecasts for 2023-28, which have a similar trajectory.

The US Energy Information Administration's (EIA) forecasts global electricity consumption to increase ~2,800 TWh from 2023-30. Over this same period, data centers' energy consumption is expected to increase ~440 TWh, or 16% of the net increase over 2023-30.

Exhibit 1: Data center electricity usage, 2020-2030
Data centers forecast to grow at a 11% CAGR over 2020-30



Source: Mytton & Ashtine, Schneider Energy Management Research Center, BofA Global Research.

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As a real-world example, we look at Dominion Energy, a US utility covered by our colleague Paul Zimbardo. Northern Virginia has the single highest concentration of data centers in the US, with over 275 sites pulling over 2.6 gigawatts (GW) of capacity. Dominion Energy is the largest utility in the region. Dominion forecasts electricity load growth to grow at a 6.6% CAGR over 2023-28. Just five data center customers represent 80% of the load growth forecast.

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[1] Mytton, D., & Ashtine, M. (2022). Sources of data center energy estimates: A comprehensive review. Joule.
[2] Avelar, V., Donovan, P., Lin, P., Torell, W., Torres Arango, M. (2023). The AI Disruption: Challenges and Guidance for Data Center Design. White Paper 110.

AI demand adds upside risks to this outlook

Artificial intelligence (AI) applications typically use graphics processing units (GPUs) given their efficiency in parallel processing. A cluster of 22,000 Nvidia H100 GPUs would require 31 megawatts (MW) of power, according to Schneider. During the training period for an AI model, these chips would operate at near 100% utilization.

NVIDIA 2023 GPU shipments = 20mn US homes

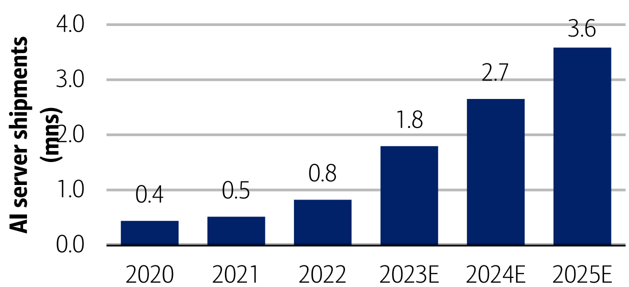
Once installed and running, NVIDIA's artificial intelligence shipments in 2023 will consume a similar amount of electricity as 20mn US homes. NVIDIA will ship ~1.4mn AI servers in calendar 2023. Assuming 100% utilization, this suggests ~18 TWh of electricity consumption. That's equivalent to the power usage of 20mn US households (at an average of 886 kWh per home).

BofA server forecasts imply >2x of AI installed base 2025

BofA's US Semiconductors & Semiconductor Capital Equipment analyst, Vivek Arya, forecasts AI server shipments to more than double in 2023 to 1.8mn, or 14% of total server shipments. By 2025, Arya sees AI server shipments reaching 3.6mn, or nearly 30% of total.

Assuming a five-year replacement cycle, AI servers comprise 3-4% of the installed base in 2022. This will increase to 12% by 2025 and 20% by 2027.

Exhibit 2: AI server shipments
60+% CAGR between 2022-25E



Source: BofA Global Research

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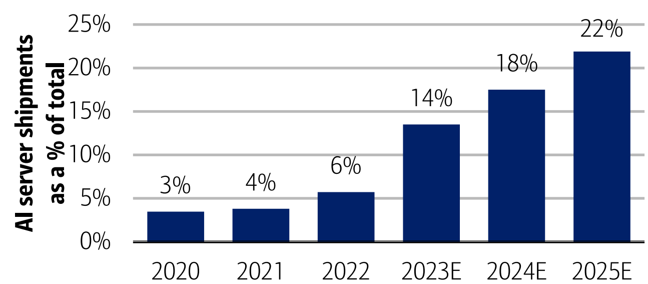
Exhibit 3: AI server shipments as % of total
AI shipments expected to reach 22% of total server shipments by 2025E



Source: BofA Global Research

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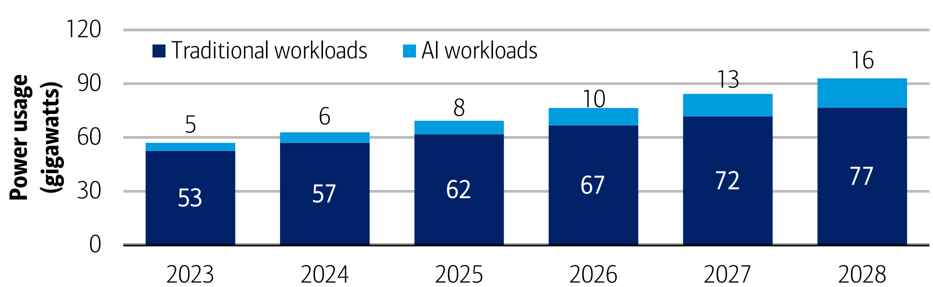
Schneider forecasts AI power usage growth trends

Schneider Electric's Energy Management Research Center forecasts that artificial intelligence (AI) applications will use 4.5 gigawatts (GW) of electricity in 2023, or 8% of total. They expect this to grow to ~8 GW by 2025 and 14-19 GW by 2028.

Exhibit 4: Global data center power usage by application
AI workloads' power usage expected to grow at a 26-33% CAGR over 2023-28



Source: Schneider Electric The AI Disruption: Challenges and Guidance for Data Center Design

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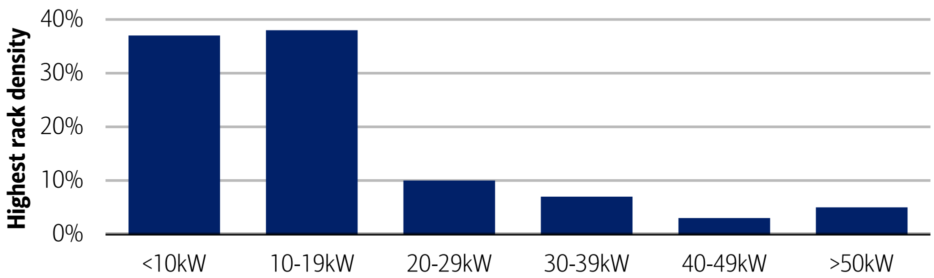
Traditional data centers have lower power density

The increasing power needs of servers are starting to run into a limiting factor – data centers' existing electrical and cooling infrastructure. There is ~250mn sq. ft. of data center infrastructure globally with an average power density of ~10 kilowatts (kW) per rack. 85% of data centers operate with maximum rack power densities of less than 30kW per rack. Keep in mind this is not an average figure – but the maximum rack density in the entire data center.

Exhibit 5: Survey of data centers' highest rack density
85% of data centers have maximum rack densities of less than 30kW per rack



Source: Uptime Institute
Note: Survey of 647 data center managers

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AI applications drive higher power & thermal density

Typical seven-foot-tall racks are divided into 48 rack units. In a traditional data center application, the rack would be filled with 24 servers each with two CPUs drawing 150 watts. Allowing for 3kW of power for storage, networking, and other items yields a total of 10kW/rack.

For AI applications, we assume 12 servers, each with 3-4 GPUs. We assume each GPU draws 700 watts (consistent with the Nvidia Hopper 100 GPU chips). Allowing for 3kW of power for storage, networking, and other items yields a total of 32kW/rack.

Exhibit 6: Comparing rack power density in traditional versus AI applications
AI applications are ~3x the power density versus traditional application

	AI	**Traditional**
Rack height (in rack units)	48	48
÷ Server height (in rack units)	4	2
Servers per rack	12	24
x GPUs or CPUs/Server	3.5	2.0
GPUs or CPUs/rack	42	48
x Watts/GPU or CPU	700	150
kW/rack for GPUs or CPUs	29	7
kW for storage, networking, etc.	3	3
Total kW/rack	**32**	**10**

Source: BofA Global Research

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AI = incremental $4bn opportunity by '25E

Reviewing the ~$37bn data infrastructure market

We estimate the data center physical infrastructure market to be $37bn in 2023E. We estimate the market has grown at a 9% CAGR (2019-23E). This includes slower growth in services & software which are tied more closely with the growth in the installed base (versus new construction). Our market definition includes **power management** (busway, electrical switchgear, power distribution units, transformers, and uninterruptible power supply systems), **thermal management** (air handlers, computer room air conditioners, evaporative cooling units, in-row cooling, rack-level fans, cooling distribution units, rear door heat exchangers, and direct-to-chip cooling plates), **IT & edge equipment** (racks, rack-level power distribution units, rack-level UPS and modular systems), and **services & software**.

Exhibit 7: Data center physical infrastructure market (2019-23E)
We estimate a $37bn market in 2023E

($bn)	2019	2020	2021	2022	2023E	'19-23E CAGR
Power management	7.8	8.1	9.1	10.4	12.1	12%
Thermal management	2.8	2.9	3.3	3.8	4.5	13%
IT & Edge	7.8	8.1	8.9	9.9	11.3	10%
Services & software	8.3	8.6	8.7	9.0	9.5	3%
Data center physical infrastructure	**26.7**	**27.8**	**30.0**	**33.2**	**37.4**	**9%**

Source: BofA Global Research, company filings
Note: Includes electrical and thermal management equipment within the data center (e.g., excluding rooftop HVAC equipment). Excludes all IT-related equipment (e.g., servers, network switches, etc.).

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Two approaches: racks and megawatts

The chart below takes BofA's AI server sale forecasts and translates those into AI racks. We then apply the incremental costs per rack of $10,000 for electrical and $20,000 for thermal. This yields a ~$4bn uplift over 2023E-25E.

Exhibit 8: Incremental AI opportunity
~$4bn of incremental opportunity over 2023-25

(in mns)	2023E	2024E	2025E
AI server sales (in '000s)	1,794	2,652	3,584
Servers/rack	12.0	12.0	12.0
AI racks (in '000s)	150	221	299
Electrical cost/rack (actual $s)	10,000	10,000	10,000
Thermal cost/rack (actual $s)	20,000	20,000	20,000
Electrical costs ($bn)	1.5	2.2	3.0
Thermal costs ($bn)	3.0	4.4	6.0
Total costs ($bn)	**4.5**	**6.6**	**9.0**

Source: BofA Global Research

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We also use Schneider Electric's forecast for AI electricity usage. We conservatively assume an incremental $1.0mn/MW for thermal and $0.5mn/MW for electrical. This approach also implies a ~$4bn uplift in the market over 2023E-25E. Note that we do not assume any uplift in IT & edge or services & software market segments.

Exhibit 9: Data center physical infrastructure market (2023E-2025E)
~$4bn of incremental opportunity over 2023-25

($bn)	2023	2024	2025	'23-'25 CAGR
Power management	12.4	15.7	17.5	19%
Thermal management	4.6	7.6	8.8	38%
IT & Edge	11.3	12.2	12.9	7%
Services & software	9.5	9.8	10.1	3%
Market size	**37.7**	**45.2**	**49.2**	**14%**
Incremental AI benefit	0.0	2.8	3.6	

Source: BofA Global Research

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What the vendors are saying

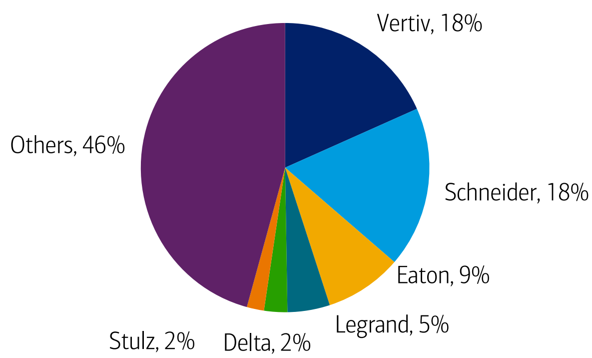
- Eaton management forecasts a 16% CAGR (2022-25) for its addressable data center end market. They note that AI data center power consumption is ~3x current data centers.

- Vertiv management forecasts a 9-12% CAGR (2023-28) for its data center market. This includes a 14-17% CAGR for cloud & colocation demand and a 3-5% CAGR for enterprise and distributed IT (e.g., server closets at offices).

- Schneider, covered by our colleague Alex Virgo, forecasts a >10% CAGR (2023-27) for its data center markets. Similar to Vertiv, this includes double-digit growth for cloud & colocation sites and mid-single-digit growth in distributed IT.

We estimate Vertiv and Schneider each have ~$7bn in data center-related revenue, with Eaton having ~$3bn. Data center related revenue comprises ~85% of Vertiv's total revenue, ~19% at Schneider, and ~14% at Eaton.

Exhibit 10: Data center infrastructure market shares (2023E)
Top three players control ~45% of the market



Source: Company filings, BofA Global Research

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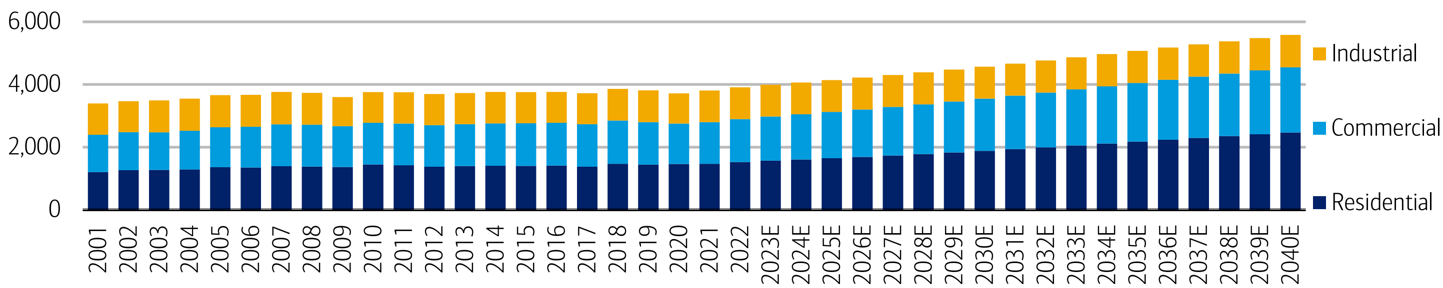
Multiple drivers of US electrical demand

US electrical demand grew at a 0.6% CAGR over the 2002-22. We estimate that increased adoption of electric vehicles (EVs), heat pumps, and electric water heaters will drive a 2.0% CAGR over 2022-40E.

This has significant implications for US grid investments, as capacity limits will start to be reached for transformers, substations, and transmission. In the last 20 years, annual US electrical demand increased by 444 TWh. We forecast 1,678 TWh being added over the next 18 years, implying capacity-focused capex would need to increase by nearly 4x.

Exhibit 11: US electrical demand (in terawatts per year) 2001–2040E
We forecast US electrical demand to grow at a 2.0% CAGR over 2022-40E versus 0.6% CAGR over 2002-22



Source: BofA Global Research, EIA

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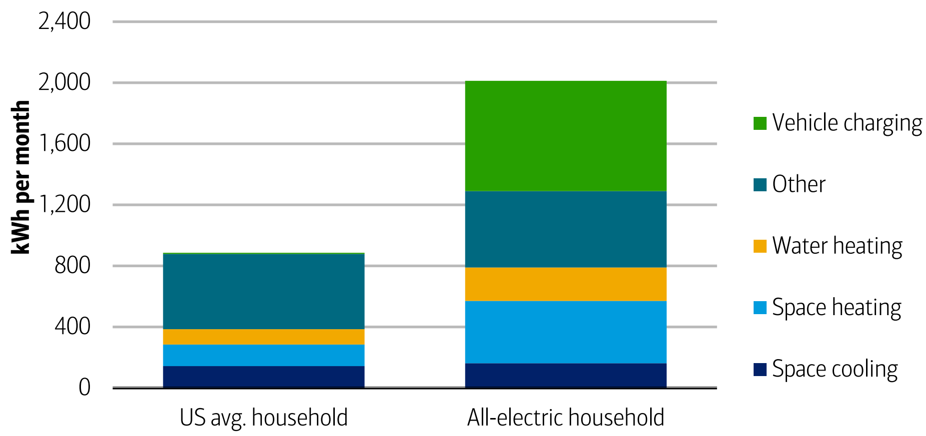
The all-electric home – 125+% more power needed

In 2022, the average US household used 886 kilowatt hours (kWh) per month, according to the Energy Information Administration (EIA). Using EIA data implies that the average all-electric home would use 2,013 kWh/month, or an 127% increase.

Currently fossil fuels power 54% of residential water heaters, 65% of space heating, and 99% of passenger vehicles. Replacing space heating would add 409 kWh/month and replacing water heaters would add 219 kWh/month. For EVs, we used average vehicle data from the Federal Highway Administration. We assume an average of 14,000 miles driven per vehicle, 1.79 vehicles per household, and 0.346 kW/mile efficiency. This yields 723 kWh/month for EV charging (assuming all charging is done at home).

Exhibit 12: Current US household electricity usage versus hypothetical all-electric household
The average household would need 127% more electricity to go all electric



Source: BofA Global Research, Energy Information Administration, Federal Highway Administration

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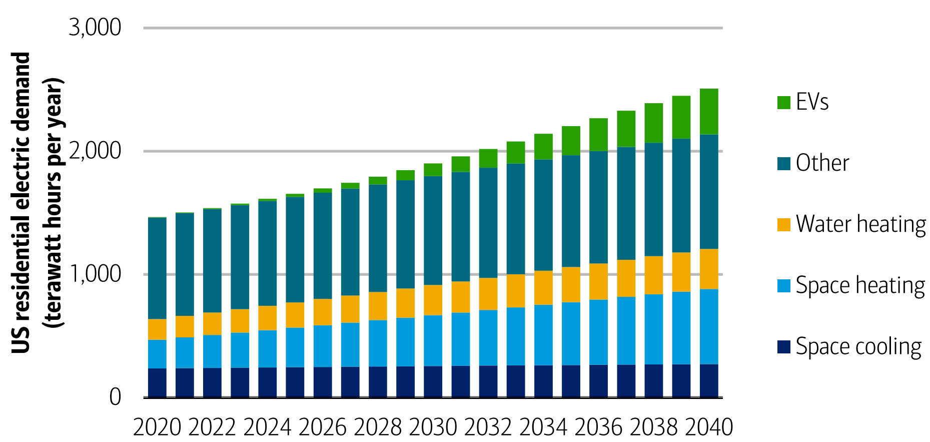
We view this as a conservative estimate for three reasons. First, we do not factor in smaller fossil fuel appliances (e.g., stoves, ovens, clothes dryers, and fireplaces). Second, we do not consider the lower efficiency of heat pumps in colder climates. Third, we do not factor in line losses between power plants and homes, which are typically 5% of total electricity generation.

By 2040, we assume electricity adoption reaches 80% of water heaters (versus 46% today), 80% for heat pumps & other electric heating (versus 35% today), and 40% for EVs (versus 1% today). We also assume 0.6% CAGR for population growth, in line with the US Census forecasts. In line with survey data, we assume 80% of EV charging is done at home.

We forecast total US residential electric demand to rise from 1,535 terawatt hours/year in 2022 to 2,508 terawatt hours/year in 2040, or a 2.8% CAGR. This compares with a 0.9% CAGR over 2002-2022.

Exhibit 13: US residential electric demand forecast
We forecast residential electric demand to grow at a 2.8% CAGR (2022-2040E)



Source: BofA Global Research

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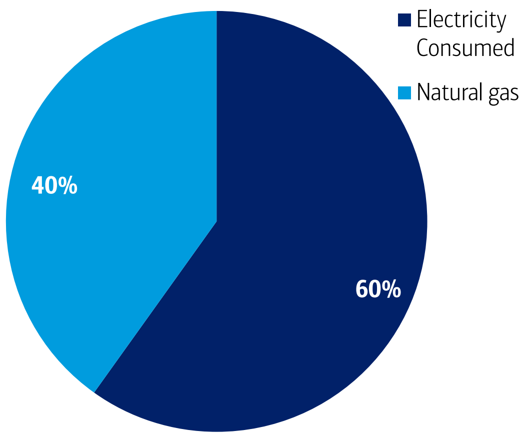
Commercial: electric heating regulations & incentives

In 2022, US commercial buildings used 1,373 terawatt hours of electricity. However, they also used 3,524bn cubic feet of natural gas, which is equivalent to an additional 920-terawatt hours of electricity. In other words, 40% of commercial buildings' total energy usage came from fossil fuels.

Exhibit 14: Commercial building energy consumption
Natural gas consumption is equivalent to 40% of total energy use



Source: BofA Global Research, EIA

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By 2040, we assume more buildings have transitioned to electrification, driven by incentives and regulations. We think that fossil fuels as a % of commercial buildings energy usage will drop to 25% by 2040, driving incremental electrification demand. We also assume 20% of EV charging outside of the home takes place at commercial buildings. This adds an additional 93-terawatt hours/year of electricity usage for commercial buildings, on our math.

Is a shift to electric heating realistic?

- **Regulations:** The state of Washington now requires all-electric heating in new buildings, with New Jersey considering similar legislation. Several cities have also banned fossil fuel heating for new construction. We expect a combination of bans and zero-carbon goals to gradual result in greater use of electricity for space heating.
- **Credits:** The 179D tax credit allows building owners to receive tax credits for upgrades to more efficient heating, ventilation, and air conditioning (HVAC) equipment. The Inflation Reduction Act increased the potential credit from $1.87/square foot to $5.00/square foot.
- **Replacement:** In 2018, the EIA estimated that 29% of US commercial square footage used electricity for primary space heating. Given an average useful life of a natural gas or oil heat furnace of 20-30 years, a significant portion of fossil fuel heated buildings will face a replacement by 2040.

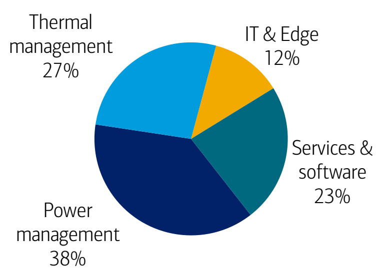
These factors yield our forecast for US commercial electric demand to rise from 1,373 TWh in 2022 to 2,046 TWh in 2040. This implies a 2.2% CAGR, which compares to a 0.6% CAGR over 2002-2022.

Stocks with data center & grid exposure

Vertiv (VRT)

Vertiv generates ~75% of revenue from data centers and distributed IT. Offerings span across power management, thermal management, distributed/edge, and services.

Exhibit 15: Vertiv revenue by offering (2023E)
Power and thermal management are Vertiv's largest offerings



Source: BofA Global Research

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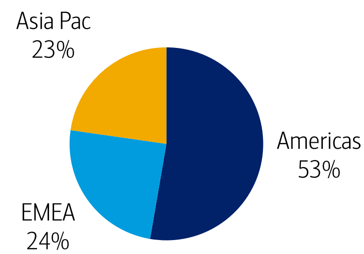
Exhibit 16: Vertiv revenue by geography (TTM 2Q23)
Americas is Vertiv's largest geography



Source: Company filings, BofA Global Research

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Eaton (ETN)

Eaton generates ~9% of revenue from data centers and an additional ~5% from distributed IT. We forecast Eaton to have approximately $2.6bn in grid-related revenue in 2023, or 11% of total revenue. Eaton has 31% of the US market in power distribution and control. Eaton's Advanced Distribution Planning software is used by 60% of North American utilities. Software offerings also include tool to automate substations and manage distributed energy resources (e.g., rooftop solar). Eaton's relationships with utilities are also improved through its strong services offerings, which span from planning & design to turnkey management, to asset protection & maintenance.

Exhibit 17: Eaton: grid-related revenue
We forecast $2.6bn of grid-related revenue in 2023E

($bn)	Revenue	Representative products
Power distribution	1.8	transformers, circuit breakers
Power transmission	0.6	substations, switchgear, capacitors, reclosers, grid automation
Grid software	0.2	Advanced Distribution Planning System, Distributed Energy Resources, automation software
Grid-related	2.6	
% of total revenue	*11%*	

Source: BofA Global Research, company filings

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General Electric (GE)

We forecast General Electric to have approximately $5.2bn in grid-related revenue in 2023, or 9% of total revenue. In addition to grid offerings, General Electric also has offerings in gas turbines ($12.7bn), wind turbines ($9.3bn), hydro turbines, steam turbines, and small module nuclear reactors. General Electric plans to spin off its energy assets in early 2024 as a new company, Vernova. In total, we forecast Vernova assets to have over $30bn of revenue in 2023, or 50% of total GE. Grid-related revenue would comprise approximately 17% of Vernova 2023 revenue, by our estimate.

GE's offerings include power transmission (e.g., step-up transformers), grid integrated solutions (e.g., high voltage direct current equipment), grid automation, hybrid (e.g., battery storage systems, solar inverters), and power conversion (e.g., power quality). GE also has ~$0.7bn in grid software (BofAe 2023 forecast), reported in the corporate segment. 30% of global utilities use GE software.

Exhibit 18: General Electric: grid-related revenue
We forecast $5.2bn in grid-related revenue in 2023E

($bn)	Revenue	Representative products
Power transmission	*1.5*	Transformers, switchgear
Grid integrated solutions	*1.2*	HVDC, substations
Grid automation	*0.6*	Controls, relays, gateways
Grid Solutions	3.3	
Grid Software	0.7	Advanced Distribution Management System, Distributed Energy Resource Management, Grid Orchestration Software
Hybrid	0.5	battery energy storage, controls, inverters for solar
Power conversion	0.7	voltage compensators, synchronous condensers, grid automation hardware
Grid-related	**5.2**	
% of total revenue	*9%*	

Source: BofA Global Research, company filings

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Aspen Technologies (AZPN)

We forecast Aspen's Digital Grid Management (DGM) software to generate $0.2bn of revenue in calendar 2023, or 18% of total revenue. Offerings include Advanced Distribution Management Systems (ADMS) software, Distributed Energy Resource Management software (DERMS), as well as related data historian and supervisory control and data acquisition (SCADA) modules. DGM has an approximately 5% market share globally but is in over 30 of the largest 100 utilities in North America.

nVent (NVT)

nVent (NVT; not covered) generated ~$375mn of sales to data centers in 2022, or ~13% of total revenue. Key offerings include cooling (cooling distribution units), power management, and racks/server cabinets. nVent's liquid cooling solutions have gained traction and the company announced capex investments to grow capacity with 2Q23 results. nVent generated approximately $140mn of revenue in 2022 from utilities and independent power producers. Offerings include enclosures for electrical equipment, power connections, grounding & surge protection, and lightning protection.

Exhibit 19: Stocks mentioned
Prices and ratings for stocks mentioned in this report

BofA Ticker	Bloomberg ticker	Company name	Price	Rating
AZPN	AZPN US	AspenTech	US$ 200.52	B-1-9
ETN	ETN US	Eaton Corp PLC	US$ 242.11	B-1-7
GE	GE US	General Electric	US$ 129.79	B-1-7
VRT	VRT US	Vertiv	US$ 49.52	C-1-7

Source: BofA Global Research

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Price objective basis & risk

AspenTech (AZPN)

We base our $255 price objective on a 25x EV/EBITDA multiple of our CY25E estimate. Our target multiple is a premium to the 19x peer average on CY24. We argue that a premium is warranted given oil & gas end-market demand strength and prospective synergies from recent acquisitions. Downside risks to our price objective are 1) oil price volatility and oil prices below $50, 2) integration risks, and 3) weakness in chemical industry budgets.

Eaton Corp PLC (ETN)

We base our $275 price objective on a 20x EV/EBITDA multiple of our 2025 estimates. Our target multiple is at a premium to the 15x peer average on 2024 estimates. We argue a premium valuation is warranted due to broad exposure to key growth end markets, expected upside from cyclical operating leverage, strong margin performance, and Eaton's less cyclical portfolio mix.

Downside risks to our PO are 1) a slower-than-expected manufacturing capex growth, 2) a more active M&A is inherently risky as it relies on the availability of accretive synergistic targets and the company's ability to integrate, and 3) the trajectory of the recovery in automotive and aerospace end markets.

General Electric Company (GE)

We base our $135 price objective on a 13x EV/EBITDA multiple of our 2025 estimates. Our target multiple is in line with the 13x peer average on 2024 estimates. We argue the pending spin-off of GE Vernova (Energy and Renewable segments) will drive a re-rating of GE Aerospace.

Downside risks to our PO are 1) the pace of the recovery in Aerospace, 2) progress on Renewable's turnaround, and 3) transactional risks relating to pending spin-off of Vernova (Renewable Energy & Power).

Vertiv (VRT)

We base our $60 price objective on an 14x EV/EBITDA of our 2025 estimates (previously 12x). Our target multiple is in line with the 14x peer average on 2024E. We argue an in line multiple is warranted given above-peers earnings growth offset by below-peer margins.

Downside risks to our price objective are 1) declines in company-owned data centers, 2) inability to execute on cost savings plans, 3) pricing deterioration due to competition, and 4) disruptions due to supply chain or manufacturing execution.

Analyst Certification

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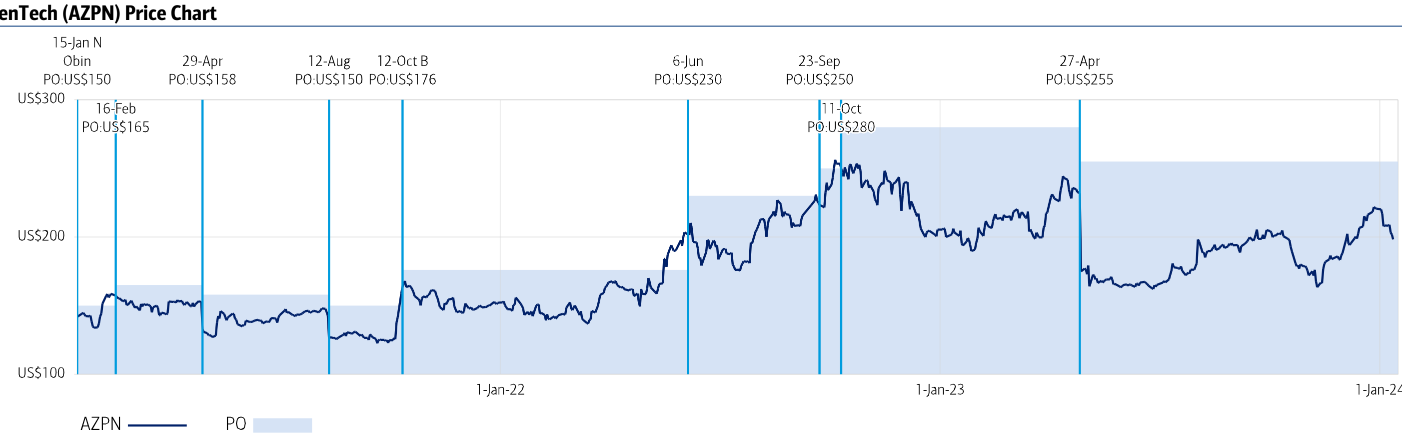
US - Multi-Industrials/Engineering and Construction Coverage Cluster

Investment rating	Company	BofA Ticker	Bloomberg symbol	Analyst
BUY				
	APi Group	APG	APG US	Andrew Obin
	AspenTech	AZPN	AZPN US	Andrew Obin
	Atmus Filtration	ATMU	ATMU US	Andrew Obin
	Dover Corp	DOV	DOV US	Andrew Obin
	Eaton Corp PLC	ETN	ETN US	Andrew Obin
	Emerson Electric Co	EMR	EMR US	Andrew Obin
	Flowserve	FLS	FLS US	Andrew Obin
	General Electric Company	GE	GE US	Andrew Obin
	Honeywell International Inc.	HON	HON US	Andrew Obin
	ITT Inc.	ITT	ITT US	Andrew Obin
	Montrose Environmental Group, Inc.	MEG	MEG US	Andrew Obin
	Parker Hannifin Corporation	PH	PH US	Andrew Obin
	PTC Inc.	PTC	PTC US	Andrew Obin
	Rush	RUSHA	RUSHA US	Andrew Obin
	Vertiv	VRT	VRT US	Andrew Obin
	Vontier	VNT	VNT US	Andrew Obin
NEUTRAL				
	3M Company	MMM	MMM US	Andrew Obin
	AMETEK Inc	AME	AME US	Andrew Obin
	Fortive Corporation	FTV	FTV US	Andrew Obin
	Johnson Controls International PLC	JCI	JCI US	Andrew Obin
	Pentair plc	PNR	PNR US	Andrew Obin
	Rockwell	ROK	ROK US	Andrew Obin
	Trane Technologies PLC	TT	TT US	Andrew Obin
UNDERPERFORM				
	Allegion	ALLE	ALLE US	Andrew Obin
	Ansys, Inc.	ANSS	ANSS US	Andrew Obin
	Carrier Global Corp.	CARR	CARR US	Andrew Obin
	Core & Main	CNM	CNM US	Andrew Obin
	Illinois Tool Works	ITW	ITW US	Andrew Obin
	John Bean Technologies	JBT	JBT US	Andrew Obin
	Keysight	KEYS	KEYS US	David Ridley-Lane, CFA

Disclosures

Important Disclosures

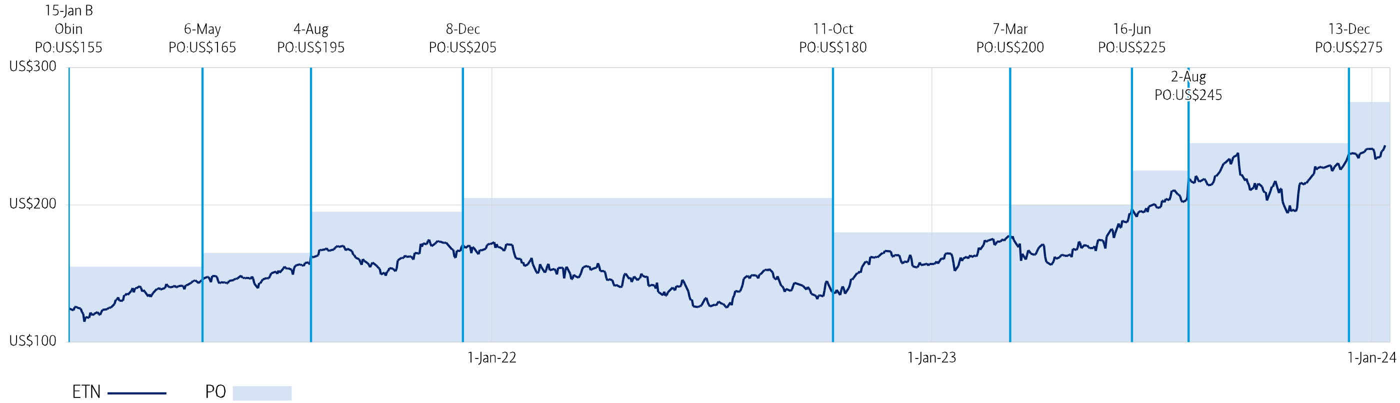
AspenTech (AZPN) Price Chart



B: Buy, N: Neutral, U: Underperform, PO: Price Objective, NA: No longer valid, NR: No Rating

The Investment Opinion System is contained at the end of the report under the heading "Fundamental Equity Opinion Key". Dark grey shading indicates the security is restricted with the opinion suspended. Medium grey shading indicates the security is under review with the opinion withdrawn. Light grey shading indicates the security is not covered. Chart is current as of a date no more than one trading day prior to the date of the report.

Eaton Corp PLC (ETN) Price Chart



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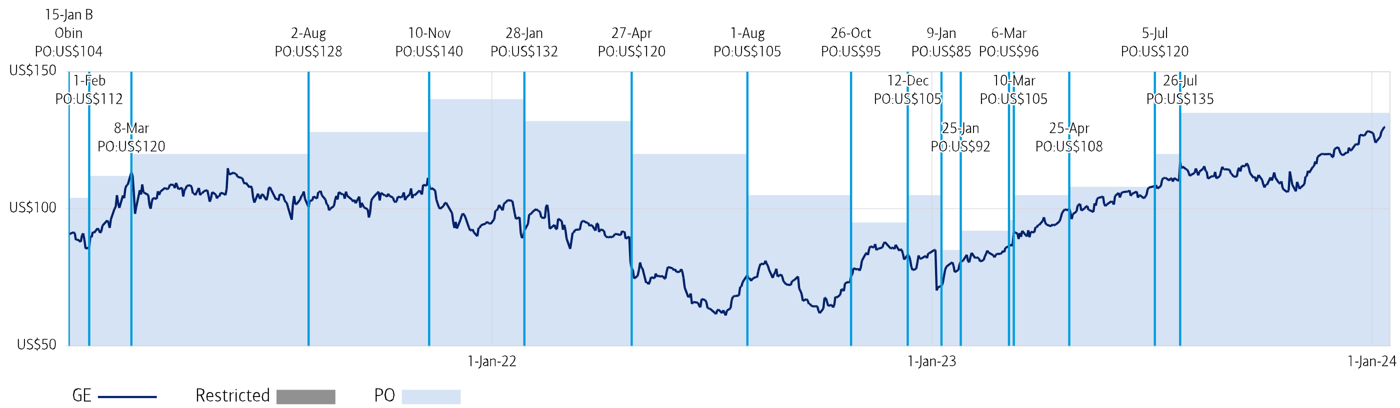
General Electric (GE) Price Chart



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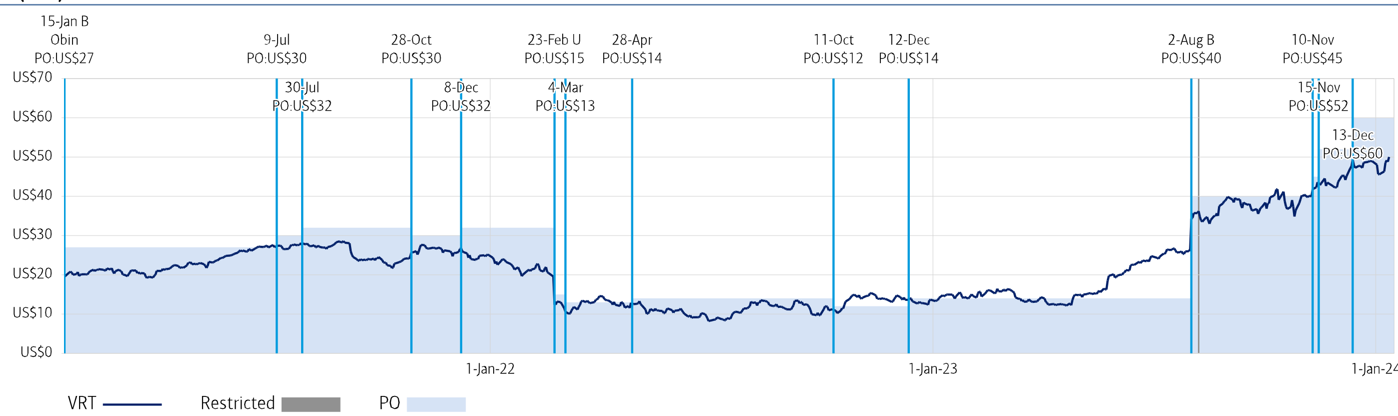
Vertiv (VRT) Price Chart



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Equity Investment Rating Distribution: Electrical Equipment Group (as of 31 Dec 2023)

Coverage Universe	Count	Percent	Inv. Banking Relationships [R1]	Count	Percent
Buy	14	53.85%	Buy	10	71.43%
Hold	6	23.08%	Hold	3	50.00%
Sell	6	23.08%	Sell	1	16.67%

Equity Investment Rating Distribution: Industrials/Multi-Industry Group (as of 31 Dec 2023)

Coverage Universe	Count	Percent	Inv. Banking Relationships [R1]	Count	Percent
Buy	45	50.56%	Buy	25	55.56%
Hold	26	29.21%	Hold	13	50.00%
Sell	18	20.22%	Sell	7	38.89%

Equity Investment Rating Distribution: Technology Group (as of 31 Dec 2023)

Coverage Universe	Count	Percent	Inv. Banking Relationships [R1]	Count	Percent
Buy	215	53.09%	Buy	111	51.63%
Hold	97	23.95%	Hold	45	46.39%
Sell	93	22.96%	Sell	24	25.81%

Equity Investment Rating Distribution: Global Group (as of 31 Dec 2023)

Coverage Universe	Count	Percent	Inv. Banking Relationships [R1]	Count	Percent
Buy	1895	53.62%	Buy	1083	57.15%
Hold	832	23.54%	Hold	454	54.57%
Sell	807	22.84%	Sell	383	47.46%

[R1] Issuers that were investment banking clients of BofA Securities or one of its affiliates within the past 12 months. For purposes of this Investment Rating Distribution, the coverage universe includes only stocks. A stock rated Neutral is included as a Hold, and a stock rated Underperform is included as a Sell.

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Investment rating	Total return expectation (within 12-month period of date of initial rating)	Ratings dispersion guidelines for coverage cluster[R2]
Buy	≥ 10%	≤ 70%
Neutral	≥ 0%	≤ 30%
Underperform	N/A	≥ 20%

[R2] Ratings dispersions may vary from time to time where BofA Global Research believes it better reflects the investment prospects of stocks in a Coverage Cluster.

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