CSIS BRIEFS

Powering the Commanding Heights

The Strategic Context of Emergent U.S. Electricity Demand Growth

By Cy McGeady

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THE ISSUE

The recent upswing in electricity demand growth forecasts has generated significant debate about the reliability, affordability, and carbon intensity of the electric-power sector. These are important questions, but they must be assessed starting with a broader perspective: Electricity demand growth has deep strategic-scale implications for the future of American economic, technological, and geopolitical leadership.

INTRODUCTION

A broad political consensus has emerged in Washington on the value of strategic economic policy. This consensus extends widely across party lines, driven by concerns over economic security, geoeconomic competition with China, and the socioeconomic value of revitalized domestic industrial and manufacturing capacity. Although substantive differences remain between the parties on the shape and scope of policy, which sectors are truly strategically vital, and just how sharp competition with China should be, it appears that a high-level and durable bipartisan interest in strategic economic policy is here to stay.

With this policymaking consensus taken as the starting point, this policy brief offers a reassessment of U.S. energy strategy. Given the strategic value of U.S. global leadership in key industrial and commercial sectors, the emergent trend of strong electricity demand growth takes on a vital new context.

There is strong evidence that a confluence of three trends—the reshoring of industry, AI-driven database expansion, and broad-based electrification—will drive a sustained era of electricity demand growth in the United States. This reverses a multidecade trend of declining growth rates, including two decades of near-zero rates of electricity demand growth at the national level.

Sustained electricity demand growth requires significant and rapid additional investment in the electric power sector. This investment must be enabled and shaped by an appropriate policy and regulatory environment if the United States is to maintain a reliable bulk power system, preserve global energy cost competitiveness, and sustain progress on declining emissions intensity.

Crucially, it would be a mistake for policymakers to consider these questions within the familiar and well-trodden political frames that have characterized energy policymaking in recent decades. Electricity, like all energy, is always a means to an end. The pending expansion of the electric power sector is the means to long-term, bipartisan, and strategic economic ends for the United States. Failure to make substantive progress on the major policy issues facing the electric power sector is to condemn broader U.S. strategic economic ambitions to failure.

KEY CONCLUSIONS

1. The most strategically valuable technologies and industries of the future are uniquely electricity intensive. Powering the commanding economic and technological heights of the twenty-first century should be the basis of American energy strategy and policymaking.
2. Sustained electricity demand growth signals an increasingly fundamental role for the electric power sector in delivering overall U.S. economic outcomes. The electricity intensity of U.S. GDP could increase for the first time since the early 1990s.
3. The strategic energy advantage of the future will be in the capacity to deliver electricity at unprecedented scale, unconstrained by infrastructure or generation capacity, and to do so at globally competitive rates, all while maintaining world-leading reliability and declining emissions intensity.
4. An electricity-focused U.S. energy strategy must pursue wide-ranging permitting reform, a robust nuclear expansion plan, and strategic-scale transmission projects.

What makes a sector *strategic?* Strategic sectors are important to national security, economic security, and domestic social welfare and heavily influence international politics. Maintaining a leading position in both innovation and production in strategic sectors is a priority for U.S. policymakers as they pursue the broad national interest.

SEMICONDUCTORS

Semiconductors, often referred to as chips, are the **backbone** of modern technology, crucial components of any high-value manufacturing, and integral to nearly all defense systems and platforms. Today, the vast **majority** of global chips are produced in Asia, with cutting-edge technology, such as sub-7 nanometer (nm) chips, produced primarily in Taiwan. This dependence on a region threatened by geopolitical tension **presents risks** to the U.S. economy that could undermine broader U.S. industrial development, acutely threaten U.S. defense technology supply chains, and constrain options in periods of diplomatic tension.

Beyond cutting-edge technology, mature chip technologies are critical for everything from cars to cell phones, and reshoring portions of this manufacturing capacity is essential to increasing supply chain resilience and limiting potential economic disruptions in the case of geopolitical tensions or natural disasters. The bipartisan support for the 2022 CHIPS and Science Act (CHIPS Act) is indicative of federal policymaking consensus on the central strategic value of chips.

ARTIFICIAL INTELLIGENCE

The unveiling of ChatGPT in 2023 made clear to the global public the transformative **potential** of AI to shape the technology frontier in the coming decades. "AI will be the defining technology of our generation," stated U.S. commerce secretary Gina Raimondo in a February 2024 **speech** at CSIS. "You can't lead in AI if you don't lead in making leading-edge chips," she contended, linking the two technologies and industries together as uniquely and strategically vital. Broad bipartisan consensus on the strategic importance of AI exists, with both the Trump and Biden administrations taking executive action, in **2019** and **2023**, respectively, to accelerate and sustain U.S. leadership in the field.

The strategic benefits delivered by AI leadership remain characterized by potential. Nonetheless, defense **applications** are numerous, including uses in information gathering or cyber warfare or as part of semiautonomous or fully autonomous weapons systems. The U.S. defense industry, armed forces, and intelligence community must maintain their technological advantage and be prepared to defend U.S. interests against AI-enabled enemies. In broader terms, AI holds the possibility of rapidly **accelerating** innovation in materials, biosciences, and other fields of **research**. This innovation will seed new technologies and new companies that in turn will help propel continued economic growth and prosperity—the basis of the United States' strategic advantage.

BATTERY MANUFACTURING

A shift is underway in the global auto-manufacturing sector toward electric vehicles (EVs), which represent the **growth segment** in a sector with declining top-line sales. Battery technology and manufacturing is arguably the most crucial component of the EV manufacturing process, and a strong upstream position in battery manufacturing is vital to any future U.S. leadership in EV manufacturing. This fact explains the scramble by car companies to invest in battery manufacturing, the central reasoning behind the Inflation Reduction Act (IRA), and the emerging consensus on battery manufacturing **articulated** across party lines.

Beyond the implications for the auto sector, current and potential battery technology applications extend into many other domains. In the electric power sector, battery storage plays an **increasingly** crucial role as a short-term balancing resource. Innovation in the domain of long-duration energy storage could deliver **technology** with global market potential. Military **applications** for battery technology are numerous, especially in the domain of drone technology, which the war in Ukraine has **demonstrated** is crucial to modern warfare. Today, China holds a price, innovation, and scale advantage in the **battery**- and **EV-manufacturing** sectors that places the United States at risk of long-term import and technology dependency. The strategic case for developing a competitive domestic manufacturing and innovation ecosystem is clear.

ELECTRICITY DEMAND IN STRATEGIC SECTORS

SEMICONDUCTOR FABRICATION

Semiconductor fabrication is an **energy-intensive** industry. Electricity is the primary type of energy consumed and is used to operate a **series** of sophisticated machines along a complex, multistage fabrication process. Large volumes of electricity are consumed to power heating, cooling, and air-circulation equipment to maintain the extremely strict temperature, humidity, and air cleanliness requirements necessary for fabrication. Ultrapure water is used for surface cleaning and requires considerable energy to distill from available water sources. TSMC, the Taiwan-based global leader in high-end semiconductor manufacturing, **consumed** over 22,000 gigawatt hours (GWh) of energy in 2022, of which 94 percent was electricity. For context, this volume is substantially larger than the roughly 17,200 GWh **produced** annually by the new Vogtle 3 and 4 nuclear reactors in Georgia.

The semiconductor industry is constantly innovating toward smaller, more capable designs. The more advanced the chip technology, the more **energy intensive** the fabrication process; a leading-edge 2 nm chip requires over three times as much energy to fabricate as a 28 nm chip. This is partially reflective of learning and efficiency gains as the chip-specific fabrication technology matures. Primarily, however, this jump in energy intensity is structural, resulting from the increased use of high-powered equipment and ultrapure water necessary to achieve precision at the microscopic level. Insofar as the future of chips is in smaller designs, the energy intensity of the sector will grow.

Various sources provide indications of the scale of new electricity demand posed by investments in U.S. fabrication capacity. A regulatory **filing** by the Arizona Public Service Company, the utility that serves a new TSMC fabrication site in Arizona, notes that initial demand will be roughly 200 megawatts (MW), but "at full build-out plant operations will require an extensive amount of electric power utilizing approximately 1,200 MW." This single site will ultimately consume electricity equivalent to the peak output of the new Vogtle 4 nuclear reactor, or equivalent to the annual **output** of roughly 36 square miles of solar panels.

Ensuring local power system balance in such cases is the responsibility of the local utility and state regulators. At the resolution of national strategy, understanding the implied cumulative energy requirements associated with policy objectives in the semiconductor sector is crucial for informing federal energy policy.

Today, the United States currently produces roughly 10 percent of global chips but none of the leading-edge chips—those with node sizes under 7 nm—targeted by the CHIPS Act. At a February 2024 **event** at CSIS, Secretary Raimondo stated that the United States is "on track to produce roughly 20 percent of the world's leading-edge logic chips by [2030]." This ambitious objective is made possible by roughly $450 billion in **private investments** in semiconductor manufacturing, materials, and equipment made in the United States since 2020, resulting in 37 new chip fabrication facilities (fabs) and expansion projects at 21 fabs. The Boston Consulting Group (BCG) **estimates** that the United States will see a surge in advanced logic chip production, reaching 28 percent of global production by 2032; likewise, overall U.S. semiconductor manufacturing capacity is forecast to grow from 10 percent to 14 percent of global capacity by 2032.

These forecasts are beset by considerable uncertainty. Open questions include just how much new manufacturing capacity these investments will deliver and, over the long term, how effective industrial policy will be at catalyzing a commercially self-sustaining, globally competitive semiconductor fabrication sector.

Today, the sector does not stand out as a major source of energy demand. U.S. Energy Information Administration (EIA) survey **data** has indicated that as of 2018 (the most recent data available), semiconductor fabrication consumed roughly 11,000 GWh. This figure is considerable but small relative to electricity consumed by other industrial sectors, such as chemicals (146,000 GWh), metals (112,000 GWh), and paper manufacturing (51,000 GWh). Nonetheless, this is a sector experiencing strong growth, and all evidence indicates that this figure will increase rapidly.

The TSMC site in Arizona discussed above, when operating at full capacity (1,200 MW), would equate to roughly 10,000 GWh in annual consumption. This site, which will eventually host three new fabs, will represent a near doubling of the 2018 sectoral electricity consumption. Beyond this site, at least 14 additional new fab investments have been announced, as have many times more expansions of existing fab facilities. Given the scale of public and private investment, the scale of announced projects and site expansions, and the fact that projects will skew toward the most energy-intensive leading-edge chip designs, total sectoral electricity consumption should expand many times over in the coming decade.

ARTIFICIAL INTELLIGENCE

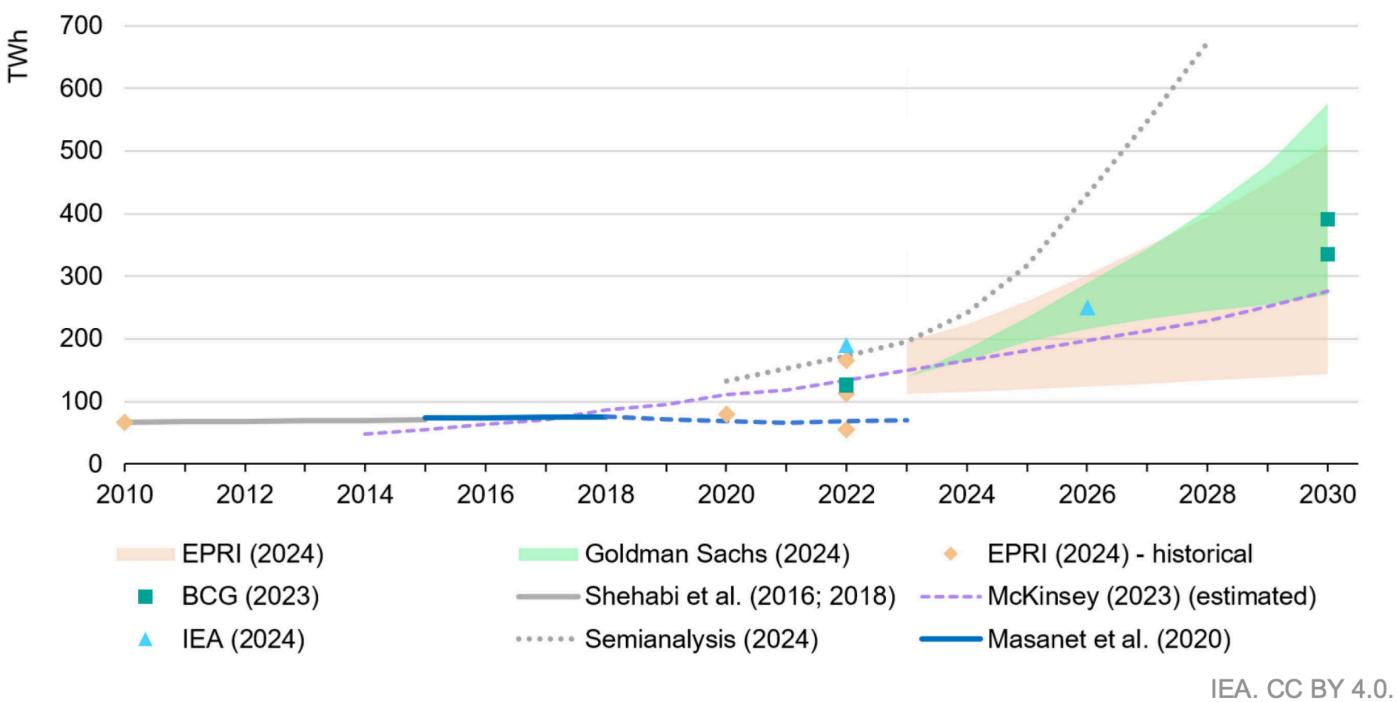
The emergence of AI models in widespread use, perhaps best symbolized by the release of ChatGPT-3 by OpenAI in 2022, heralded the onset of a new era for computing and technology writ large. A global technology race has developed to train and deploy the most cutting-edge AI models, which has driven requirements for expanded data center capacity and initiated a surge in data center investment and construction. Goldman Sachs has **estimated** that tech firms will spend roughly $1 trillion on AI capital investments over the next decade.

The growing demand for computational capacity has accelerated a long-standing trend of data center expansion in the United States and worldwide. The International Energy Agency (IEA) has **estimated** that data centers consumed about 200 terrawatt hours (TWh) in 2022, which represents 5 percent of the annual U.S. electricity consumption of roughly 4,000 TWh. **BCG** placed the 2022 figure at roughly 130 TWh, and the Electric Power Research Institute placed the 2023 figure at 150 TWh in 2023. A single authoritative figure for U.S. data center energy consumption does not exist, as the EIA does not currently collect and publish this data; this is a glaring gap in energy system transparency and represents a small but obvious and relatively straightforward priority for policymakers.

Regardless of the figure used, today's data center energy consumption already represents significant growth over the last decade. A 2016 Lawrence Berkeley National Laboratory (LBNL) study estimated 30 TWh of consumption in 2000; relative to this figure, the IEA estimate of 200 TWh of consumption in 2022 represents a compound annual growth rate (CAGR) of roughly 9 percent.

The advent of AI has accelerated growth in recent years and pushed data center energy consumption onto a faster growth trajectory. AI is far more energy intensive than the digital technology it replaces, and because of the vast potential for novel capabilities and applications, it may expand the overall market for digital services considerably. The development of AI models is a one-off process that is uniquely energy intensive; ChatGPT-4 is estimated to have **consumed** 62 GWh of electricity to train. Each new iteration of a model deployed by each firm in the sector requires such an initial energy investment; given the proliferation of AI firms and AI models, the energy consumed for model training rapidly adds up.

Figure 1: U.S. Data Center Electricity Demand Growth from Different Sources, 2010-2030



Notes: The ranges in the figure correspond to the minimum and maximum projections provided in the selected sources. From Shehabi (2018), "Best practices" and "Frozen Efficiency"; from BCG (2022), "GenAI min" and "GenAI max"; from Goldman Sachs (2024), "Bear case with AI" and "Bull case with AI"; from EPRI (2024), the lower bound of "Low growth" and the upper bound of "Higher growth" scenarios are shown. Demand figures for McKinsey (2023) are IEA estimates based on reported data centre power consumption, assuming a utilisation rate of 60% and PUE of 1.5. Masanet et al. (2020) provides estimates for North America. These have been adjusted with a factor of 0.9 to correspond to the US values.

Source: Shehabi et al. (2016), United States Data Center Energy Usage Report; Shehabi et al. (2018), Data center growth in the United States: decoupling the demand for services from electricity use; Masanet et al. (2020), Recalibrating global data center energy-use estimates; BCG (2023), The impact of GenAI on Electricity: How GenAI is Fueling the Data Center Boom in the U.S.; McKinsey (2023), Investing in the rising data center economy; IEA (2024), Electricity 2024; Goldman Sachs (2024), AI, data centers and the coming US power demand surge; Semianalysis (2024), AI Datacenter Energy Dilemma - Race for AI Datacenter Space; EPRI (2024), Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption.

Source: International Energy Agency (IEA), Electricity Mid-Year Update (Paris: IEA, July 2024), 24, https://www.iea.org/reports/electricity-mid-year-update-july-2024.

Once a model is operational and integrated into a commercial service, individual AI queries remain highly energy intensive. **Research** indicates that queries on ChatGPT are 10 times as energy intensive as a traditional Google search query; other AI models and services may be even more energy intensive. Because of the interactive nature of the current suite of chat services, these AI platforms tend to induce sustained engagement, which increases the number of queries overall and therefore adds to the cumulative increase in total energy consumption.

These bullish indicators should be **tempered** by prospects for continued progress on efficiency, which occurs in parallel to data center expansion. Historically, the relationship between total computational capacity and total electricity consumption has not scaled linearly. Considerable progress has been made on data center efficiency over the last two decades, a result that has slowed overall electricity demand growth from the sector despite growing computational capacity. Technology firms have a direct and strong incentive to invest and innovate toward efficiency given that energy costs are the primary operational cost for service delivery. Improved efficiency offers a direct competitive edge. There is also reason to believe that the current unique energy intensity of AI services (e.g., 10 times that of a Google query) will fall as firms shift research and investment prioritization away from performance toward efficiency gains as the technology matures and profitable commercial implementation takes priority. On the other hand, sectoral efficiency metrics such as power usage effectiveness (PUE) have shown **slower progress** recently, suggesting that the easiest gains in data center design and optimization have been achieved and that the rate of energy efficiency gains may decrease in the future.

Despite the uncertainty surrounding efficiency gains, it is abundantly clear that the net impact of AI is growing data center electricity consumption, albeit within a wide range of estimates. A recent **study** from the Electric Power Research Institute has shown that data centers could add up to 252 TWh of annual consumption by 2030 in a high-growth case. The IEA has estimated that annual data center consumption could grow by **60 TWh** by 2026, and BCG has estimated it will grow by **260 TWh** by 2030. At the extreme end of the forecast range, Goldman Sachs has calculated that annual consumption could grow by **650 TWh** by 2030, a forecast predicated on a very bearish view for future efficiency gains.

At the local utility level, rapid growth is clearly imminent. Dominion Energy Virginia, the electric utility that serves the Virginia market, has **reported** that it expects an incremental 10.5 GW of data center demand expansion by 2038, which equates to nearly 91 TWh of new annual consumption in Virginia alone. Numerous additional utilities and grid operators are likewise reporting surges in datacenter interconnection requests and updating local demand growth forecasts accordingly.

AI remains a novel technology with largely **undeveloped** commercial applications in a market structured to reward energy efficiency. These facts explain the wide range of forecasts; for policymakers, the takeaway is that the ultimate rate of electricity demand growth from this sector is uncertain, but it is nonetheless strong enough to place considerable strain on the U.S. electric power sector.

BATTERY MANUFACTURING

As the U.S. auto-manufacturing industry seeks to recover a leadership position from China on EVs, a strong position upstream in the supply chain in battery manufacturing is required. Battery manufacturing is energy intensive, consuming both electricity and natural gas in a process that converts raw materials into high-value, relatively commoditized products.

Considerable academic literature exists about the energy intensity of this process. A review of these estimates—including **F. Degen et al.**, **Florian Degen and Marius Schütte**, **Qiang Dai et al.**, and **Simon Davidsson Kurland**—delivers an estimated energy requirement of 44 kWh to produce 1 kWh of battery capacity. The best-selling electric car of 2023, the Tesla Model Y, has a **battery size** of 75 kWh, which, using the figure above, would imply that 3,300 kWh of electricity was consumed to produce the battery; a typical household consumes 10,000 kWh annually.

The policy support created by the IRA has catalyzed a **surge** in EV battery manufacturing investment across the United States. Several states will rapidly develop significant manufacturing capacity, such as Michigan (140 GWh/year), Georgia (136 GWh/year), and Tennessee (128 GWh/year). In total, the United States has been **forecasted** to develop over 1,000 GWh/year of manufacturing capacity by 2030. Assuming this forecast is met, applying the energy-intensity figure above would suggest the consumption of roughly 44 TWh of electricity by the battery manufacturing sector annually by 2030, up from effectively zero consumption in 2020. Set against the current annual U.S. electricity consumption of roughly 4,000 TWh, this represents approximately 0.68 percent of all U.S. consumption.

Although small relative to the growth projections in the data center sector, these volumes are nonetheless significant. Put in perspective, this volume is larger than the electricity consumed by 20 individual states in 2022; it is just larger than the electricity consumed by the entire state of Kansas, for example, which **consumed** 42 TWh in 2022.

This estimate notably does not account for the upstream mining and minerals processing aspects of the supply chain, which it should be noted, are likewise sectors with strategic significance and bipartisan policy support. Tax credits for battery manufacturing and EVs have **domestic sourcing** conditions that are intended to induce investment in domestic mining and minerals processing. Less investment has flowed into this sector to date largely because of the immense environmental permitting and social license issues it faces relative to the cleaner profiles of battery manufacturing, semiconductor fabrication, and data centers. Mining and especially minerals processing are incredibly **energy intensive**. Should policy successfully catalyze significant investment and sectoral expansion, growth in electricity demand from this upstream sector could easily surpass the entire electricity consumption associated with downstream battery manufacturing.

ELECTRIFICATION

The sector-specific developments detailed above coincide with a broad economy-wide trend toward electrification, the process by which fuel-burning technology is replaced with electricity-powered technology. The major loci of electrification are in the transportation sector through the adoption of EVs, in the building sector through electric heating and cooling technologies, and in the industrial sector through a myriad of process and technology changes.

The rate of electrification and its impact on the grid are uniquely difficult to track and forecast. Data centers and manufacturing sites represent a relatively small number of new grid connection points that each consume extremely large volumes of electricity. In contrast, electrification represents small incremental demand expansions at millions of dispersed points across the grid, resulting from millions of dispersed household and commercial decisions driven by consumer trends, commercial developments, and uncertain local, state, and federal policy decisions.

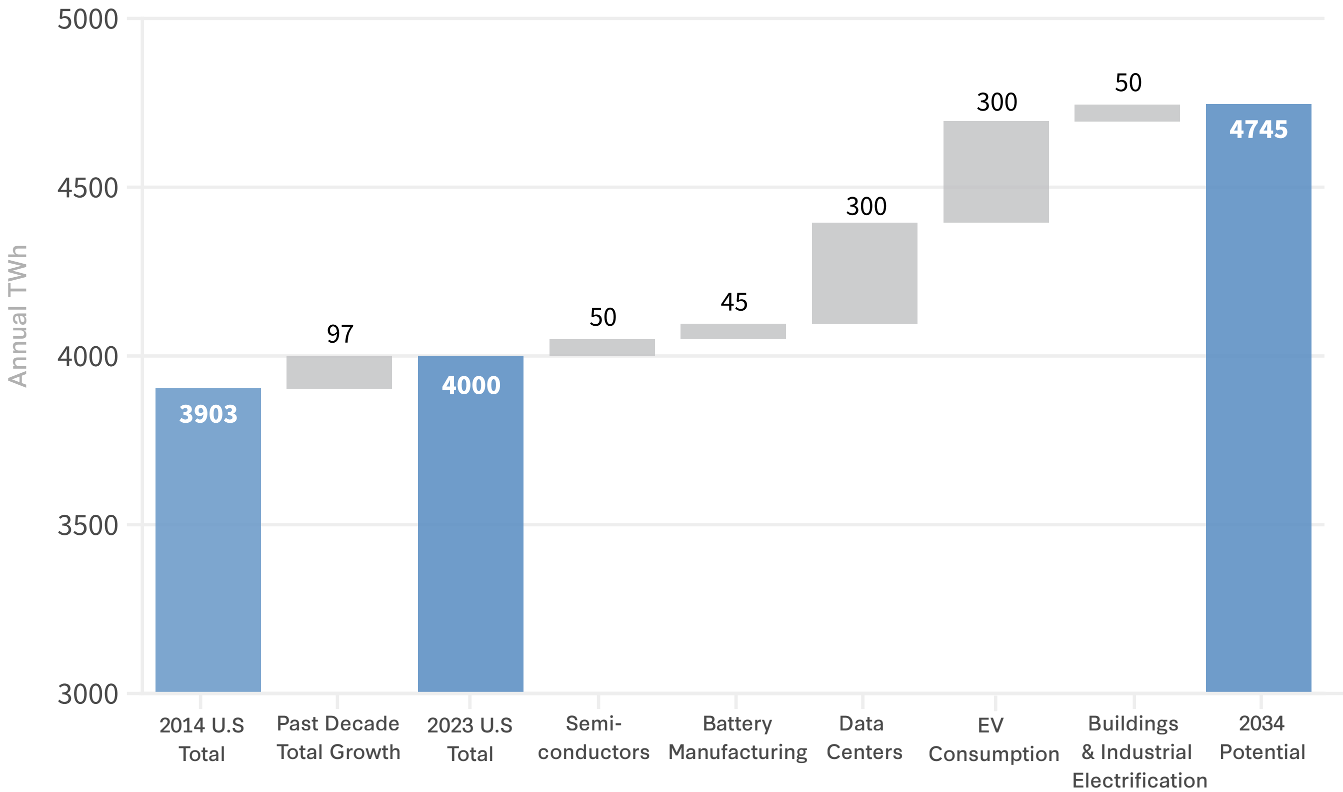
EVs are the biggest source of potential new electricity demand. In 2023, EVs **consumed** nearly 8 TWh of electricity. This figure will grow rapidly in the decades to come. A 2023 National Renewable Energy Laboratory (NREL) **study** has found that EVs could consume nearly 930 TWh annually by 2050 in a rapid adoption scenario that models EVs as 100 percent of light-duty vehicle (LDV) sales by 2035. Slower uptake scenarios, such as 65 percent of LDV sales by 2035, result in 750 TWh of annual electricity demand by 2050. Overall electricity demand from EVs and their impact on the U.S. power sector depend on the rate of EV adoption, changes in driving patterns, and, crucially, the degree to which EV charging is optimized with grid balancing operations, all of which contribute to considerable uncertainty over timing and scale. In the near term, **modeling work** from Evolved Energy Research has shown that well over 300 TWh of new annual electricity demand could arise by 2030 from electrified transport and that even very slow EV uptake will result in 60 TWh of transport electricity demand by 2030.

Electrification in buildings is another source of electricity demand growth, albeit likely smaller than the growth potential posed by EVs, shaped by choices such as the substitution of fuel-burning space and water heating with electric heat pumps. The NREL **Electrification Futures Studies** project has shown that medium- to high-electrification scenarios drive consumption growth estimates of 30–60 TWh by 2034 and 123–250 TWh by 2050. The impact on the electric power sector will be more acute in specific geographies and at specific peak demand moments. One **study** modeled a rerun of the 2019 polar vortex winter storm under conditions of deep electrified heating; the result was a peak load of 690 GW in the Northeast and upper Midwest versus an actualized peak load of 275 GW during the event, a 2.5 times increase. The authors of the study have posited several ways in which efficiency and other changes could partially mitigate the peak load impact, but the potential challenge for grid operators in these regions is clear.

Broad industrial electrification represents another source of potential demand growth. NREL has forecasted that industrial electricity consumption could grow by 16 TWh by 2034 and 111 TWh by 2050. This result is uncertain given that the technologies for replacing existing fuel-combusting processes are relatively nascent or constrained by high costs. Crucially, the model excludes electrification in key energy-intensive industries, such as **cement** and **steelmaking**, that are today the subject of considerable electrification research and investment. The energy demands represented by these sectors are significant and may drive electricity consumption growth indirectly via the substitution of fossil fuels with green hydrogen, the production of which consumes electricity. A single green steel **project** in Ohio supported by the Department of Energy (DOE) could eventually require 8.3 TWh of electricity annually, more than the annual electricity consumption of the state of Vermont.

Industrial electrification also intersects with the expansion of the strategic sectors surveyed above. In battery manufacturing, efforts are **underway** to electrify processes that currently burn natural gas. This will reduce the overall energy and emissions intensity but increase the electricity intensity of battery production. Extending this broadly, if the U.S. power grid will allow it, the reindustrialization of the American economy will be far more electricity-intensive but far less emissions and energy-intensive than past eras of industrialization.

Figure 2: Key Sources of Electricity Demand Growth



Note: This should be interpreted as a non-exhaustive survey of sources of demand growth, not as a forecast.
Source: Author's estimates, "Annual Energy Review," U.S. Energy Information Administration (EIA), 2024, https://www.eia.gov/ totalenergy/data/annual/.

IMPLICATIONS FOR THE U.S. ELECTRIC POWER SECTOR

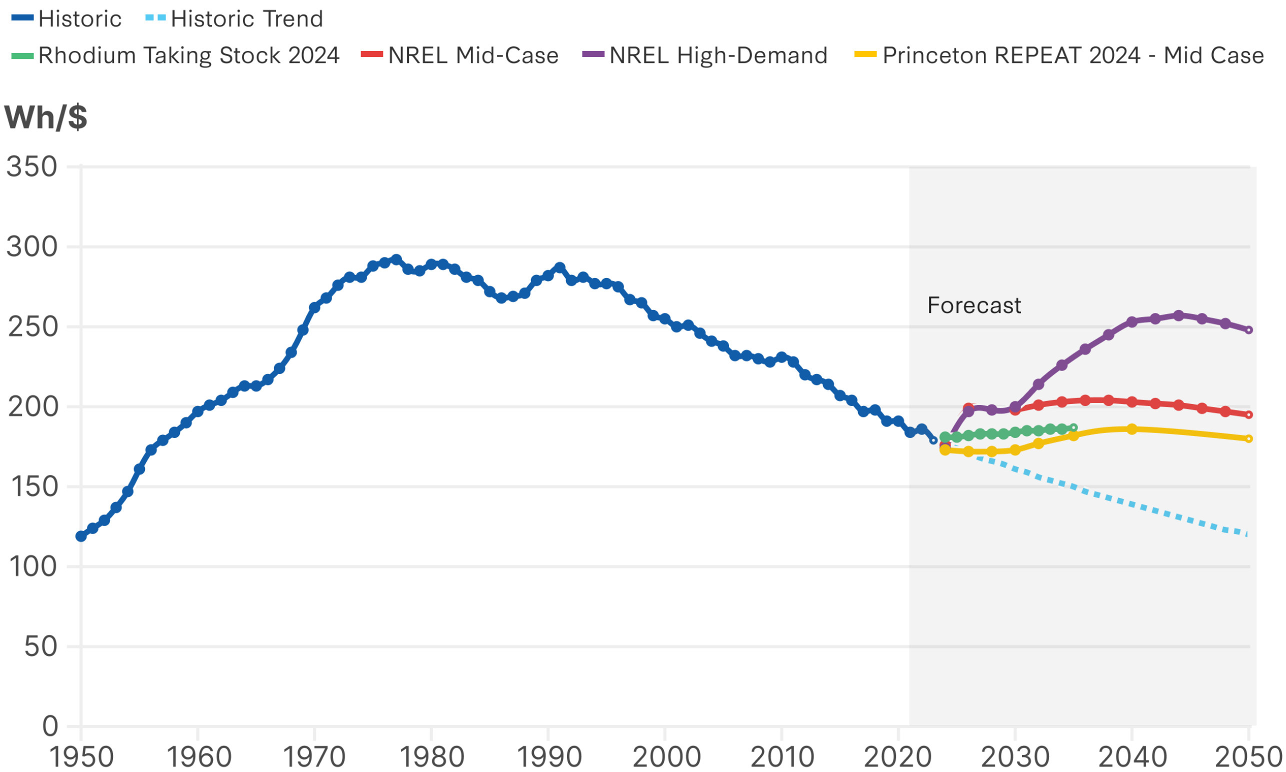
Two key conclusions about electricity demand growth can be drawn from the survey above. First, each of these industries—and in the case of electrification, the overall trend—has the potential to represent vast volumes of new electricity demand, yet each of the surveyed sectors is beset by considerable uncertainty. In chips, it remains unclear how fast the United States can reignite and scale an industry that faces major labor and cost challenges. In AI, nobody knows how fast efficiency gains will offset demand or the uptake rate of AI services. In battery manufacturing, ultimate scale is dictated by the downstream adoption of EVs, which is a major unknown variable.

The realization of a relatively bearish case for demand growth in any one of these sectors could easily be offset by bullish outcomes in another. Even taking low-end demand growth cases from each of these domains would in sum still deliver a robust demand growth story that outperforms the past two decades of near-zero growth rates for the sector.

Furthermore, this brief must be understood as a non-exhaustive survey; other sectors could see expansions enabled by policy or other commercial factors that create additional potential for electricity demand growth. Electrolysis-based hydrogen production could eventually scale to consume vast volumes of electricity. Solar panel manufacturing is another energy-intensive industry slated for policy-backed expansion. As with battery manufacturing, it should induce considerable upstream investment in the mining and minerals processing sectors, which could themselves become major sources of electricity demand growth. This survey also takes no account of population and broader economic growth, which will no doubt continue to contribute incremental electricity demand growth to the overall picture as well.

In short, despite wide ranges of uncertainty in specific industries, policymakers can nonetheless derive a baseline of certainty on which to establish and motivate policy in the energy sector. The exact speed, scale, and distribution of this growth will reveal itself in time; these relatively fine details are the appropriate subject of state

Figure 3: Electricity Intensity of U.S. GDP



Source: "Annual Energy Review," EIA; "Explore Our Results," REPEAT Project, Princeton University, https://repeatproject.org/results?comparison=benchmark&state=national&page=1&limit=25; "Standard Scenarios," NREL, https://www.nrel.gov/analysis/standard-scenarios.html; and Ben King et al., *Taking Stock 2024: US Energy and Emissions Outlook* (New York: Rhodium Group, July 2024), https://rhg.com/research/taking-stock-2024/.

policymakers and utility planners responsible for local system balancing. Federal policymakers should proceed with a baseline of certainty in mind and seek to create a policy environment that delivers an expansion of the electric power that enables rather than constrains national economic and security strategy.

Second, the relative certainty of sustained electricity demand growth points to an increasingly fundamental role for the electric power sector in delivering overall economic outcomes in the United States. The key metric for understanding this relationship is the electricity intensity of U.S. gross domestic product (GDP). This indicator grew rapidly in the early stages of the postwar economic boom but peaked when the Arab oil embargo crisis of the 1970s initiated a new emphasis on energy efficiency. Given the combined potential for electricity demand growth across numerous vectors, all indications are that this metric should arrest its long-term decline, stabilize, and trend upward, potentially approaching the heights reached in the 1970s.

This metric is indicative of underlying compositional patterns in the U.S. economy. Though improved efficiency in households and business are part of the story, a major component is the increased contribution to GDP from services relative to energy-intensive industry. Insofar as a policymaking consensus coalesces around the strategic goal of revitalized U.S. industrial and manufacturing capacity, the incremental sources of economic growth will be far more energy intensive than in recent decades. Because of structural commercial and technological trends, the composition of this new surge in energy demand will skew heavily toward electricity.

Crucially, a shift upward in the electricity intensity of U.S. GDP can and will occur even as the overall energy intensity and emissions intensity of GDP continue to fall. This is made possible by the inherent efficiency of electricity relative to fuel combustion in end-use applications and the ongoing fall in the carbon intensity of electricity generation. As electricity incrementally displaces end-consumer fuel use in residential, commercial, and industrial sectors, electricity will grow to represent an ever-larger share of the total U.S. energy system. This shift has far-reaching implications for U.S. energy strategy.

IMPLICATIONS FOR U.S. ENERGY STRATEGY

This brief began with a premise about a durable political consensus on industrial expansion and economic competition with China as core U.S. strategic objectives. The survey conducted by this brief demonstrates that three of the most prominent industries are uniquely electricity intensive. In combination with long-term trends toward electrification, this will require the U.S. electric power sector to deliver vast new volumes of electricity over the coming decades. This leads to a broader and deeper conclusion that U.S. economic output—which forms the basis of the country's economic, technological, and military advantage—will grow increasingly electricity intensive.

These findings should anchor a new long-term American energy strategy. For decades, U.S. energy strategy has revolved around U.S. exposure to global oil markets, which resulted in policy that focused abroad on secure and stable flows of oil in global markets and domestically on energy independence. These organizing concepts are increasingly out of date; as of 2019, the United States has been a net energy **exporter,** and in 2023, it was the world's largest producer of both **oil** and **natural gas**. **Estimates** vary, but global oil demand will likely **peak** within 10 to 15 years.

Meanwhile, the most valuable technologies and industries of the future are uniquely electricity intensive. Powering the commanding economic and technology heights of the twenty-first century should be the basis of American energy strategy and policymaking.

In future policy briefs, the CSIS Energy Security and Climate Change program will examine in more detail the federal role in the electric power sector given this new strategic context and assess policy options. Nonetheless, the overall contours of policy objectives are clear and well established.

Broad expansion in both the industrial and electric power sectors requires a large amount of new physical construction. The United States must build industrial and manufacturing sites; roads and rail lines; mines; wind and solar projects; hydrogen, CO_2, and natural gas pipelines; nuclear power stations; transmission lines; and more—all at a speed with which it is unfamiliar. Permitting reform is crucial in enabling faster, lower-cost deployment of these projects at pace to keep up with national strategic objectives.

Large-scale expansion in the electric power sector requires investment in new generation and grid resources. On the generation side, additions will be a mix of renewables, storage, gas, and nuclear resources. U.S. utilities and independent developers have demonstrated a capacity to build these resources at speed and scale, apart from offshore wind and nuclear. The former has a clear pipeline of projects that will slowly deliver capacity and deployment expertise, albeit behind the expected timelines following several years of rampant cost inflation.

Accordingly, *nuclear power* is the second area that will require ambitious, strategically oriented policymaking at the federal level. The **recently passed** Advance Act is indicative of the bipartisan opportunity. More can be done to cement the project pipeline for ready-to-deploy reactors in the near term, until advanced reactor technologies are ready for commercial scale in the 2030s. Policymakers need to take advantage of the expensively won engineering lessons, labor pool experience, and supply chain investments delivered by the Vogtle 3 and 4 projects before they are lost.

Rapidly expanding supply and demand in the electric power sector will require a larger and more efficient connective tissue. Transmission is the third area requiring policymaking focus. The status quo regulatory and policy equilibrium favors investment in projects that do not deliver maximum strategic value and hold back the potential for efficiency and scale in the sector. Specifically, high-voltage transmission networks deliver strategic public goods that no commercial entity or state policymaker is positioned to value or champion. No matter the specific generation resource mix of the future, big grids will be the backbone of the future energy system and will provide reliability and flexibility for the overall development pathway for 100 years or more. Federal policymakers need to develop new policy and partnership models with utilities and state policymakers to deliver ambitious transmission projects that provide strategic-scale benefits to the nation.

The strategic energy advantage of the future will be in the capacity to deliver electricity at unprecedented scale, unconstrained by infrastructure or generation capacity, and to do so at globally competitive rates, all while maintaining world-leading reliability and declining emissions intensity. Policymakers should approach emerging energy and electric power sector policy debates with a clear view of the strategic stakes. ■

Cy McGeady *is a fellow with the Energy Security and Climate Change Program at the Center for Strategic and International Studies in Washington, D.C.* *The author would like to thank former CSIS interns* ***Hatley Post*** *and* ***Dylan Kassin*** *for their valuable contributions to this work.*

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