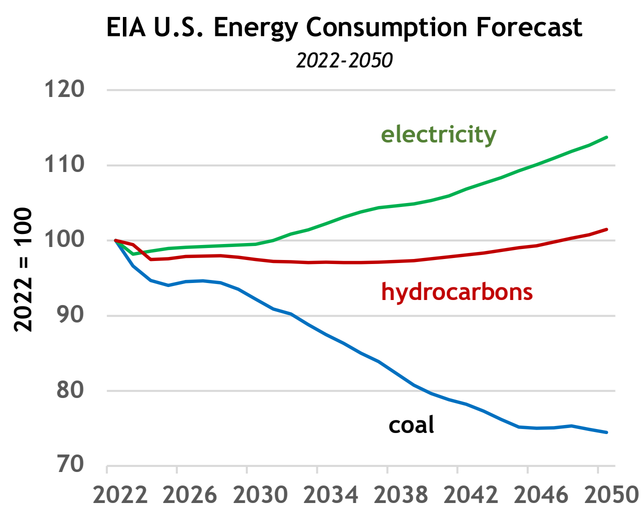
The Electrification of America

June 2023

The Future of the U.S. Grid

National goals of a carbon-free grid by 2035[1] have inspired broad climate-focused initiatives across the U.S. economy. These include new regulations at the state level[2], accelerating schedules from automakers for replacing gas vehicles with EVs in their product lineups[3], greater funding for renewables construction, and increasingly limited financing for carbon-intensive power plants[4]. All these initiatives are converging on a century-old power grid that faces long lead times for construction of new capacity to accommodate the accelerating growth in demand. In their Annual Energy Outlook 2023, the EIA forecasts continuing growth in U.S. energy consumption to 2050 with electricity taking an increasingly larger share of the total[5]. The impact on power prices and the reliability of power supply will be profound.



- **Forecasts for power demand are too low.** Demand for power will outpace the capacity of the grid to supply it. Weather-normalized load growth continues to strengthen as EVs increase their share of the domestic auto fleet; state regulations of building codes and transportation are becoming more onerous; the migration of corporate data to cloud infrastructure is creating new sources of demand for data centers; and work-from-home trends are increasing residential demand without any loss in commercial demand because offices that are only partially staffed still require power.

- **Growth in power supply is too slow.** Changing environmental regulations are forcing coal and gas-fired plants to retire faster than they can be replaced and new-build development queues for renewable generation are clogged and delaying completion of new plants.

- **Stability of the grid is changing for the worse.** Reserve margins based on maximum expected demand now growing faster than capacity will fall below prudent safety margin minimums and will weaken the capability of the grid to accommodate short-term swings in demand. Electricity prices will become more volatile and more expensive when the costs of renewables construction are added to the rate base.

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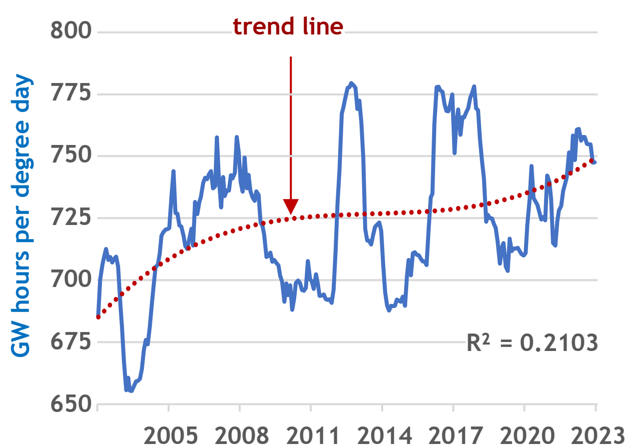
Forecasts for Power Demand Are Too Low

Secular growth in demand for power is distorted by seasonal weather patterns and global economic growth. The first quarter of 2023 was one of the warmest in the U.S. in recent history and demand for power fell well below the prior year 2022 as well as below 3 and 7-year averages. Despite the milder weather, however, demand for power continues to strengthen when normalized for variations in weather conditions.

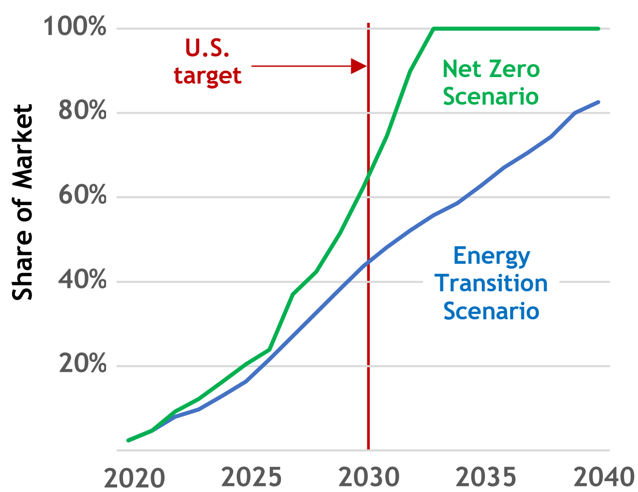
The National Centers for Environmental Information of NOAA (National Oceanic and Atmospheric Administration) tracks several climate statistics, which include cooling degree days (CDD) and heating degree days (HDD). Together heating and cooling degree days measure the weather-related demand for power. A rolling 12-month total of gigawatt hours per degree day across the U.S. provides a measure of power demand normalized for weather and shows a steady upward trend since 2001. Even in the face of unseasonably mild weather the underlying demand for power continues to increase[6].

Rolling 12 Month GW Hours per U.S. Degree Day[6]



In addition to underlying growth in power consumption from current users, the grid must also be prepared to service new sources of demand, which will come from (i) the increasing penetration of the domestic auto fleet by electric vehicles (EVs), (ii) climate-directed trends and new government programs to invest in domestic manufacturing,(iii) evolving state regulations of building codes, products, and transportation, (iv) the migration of corporate data to cloud infrastructure that is expanding demand for data centers[7], and (iv) work-from-home trends that have increased daytime residential demand for power without any reduction of commercial demand from partially-staffed offices.

Projected U.S. New Car EV Sales Scenarios



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State and federal regulations are accelerating the timelines of Energy Transition Scenarios that target 2035 as the year when EVs will achieve a 60% share of U.S. new auto sales. California now requires all new vehicle sales to be EVs by 2035[8] while auto makers are enacting their own targets for 100% EV product offerings, which are significantly ahead of the stated goals of the Biden administration[9]. They come as early as 2026 for Audi; 2030 for BMW, Mercedes, and Toyota; and as late as 2035 for GM and Volkswagen. The differences between Biden's 2030 50% Energy Transition Target, the 2030 64% Net Zero Target, and the stated goals of auto manufacturers are significant. A 100% new car product offering of EVs in 2030 would require an estimated 38,000 MWs of additional electricity generation capacity, which would need to operate 24/7[10].

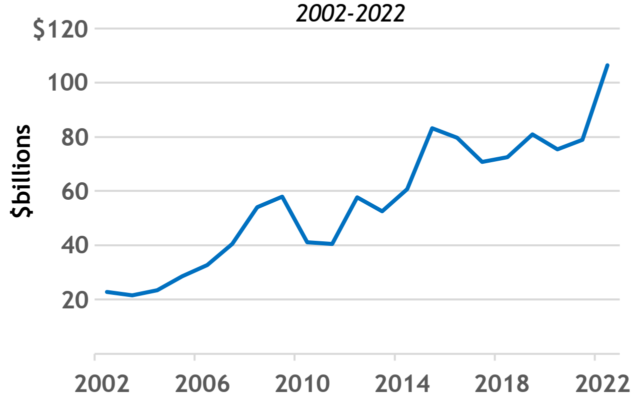
Other sources of new demand are emerging from state regulations targeting specific carbon-emitting products. New York recently became the first state to ban gas stoves, gas furnaces, and propane heating in new construction by 2026. California banned all gas-powered lawn equipment by 2024[11], which would add 4 million MW hours of electricity demand per year if adopted nationally.

Manufacturing accounted for a quarter of U.S. power consumption in 2022 and has been growing at about 2% annually since 2002 versus 11.3% nationally across all sectors[12]. This is about to change.

Supply chain pressures from the pandemic, the Chips and Science Act, and the Inflation Reduction Act of 2022 have triggered significant new investment in domestic manufacturing. Spending on new construction of manufacturing facilities is up 50% since 2017 and demand for electricity to operate them can be expected to grow proportionally in the near future[13].

U.S. Manufacturing Capacity Put in Place[12]

2002-2022



Another source of new demand will come from data centers as the scale and economics of data management force corporations accelerate the migration of their data to cloud infrastructure. According to a McKinsey study on the data center economy, U.S data center demand is forecast to grow over 9% per year from 2022 to 2030. That growth will put another 17 GW of demand for on the grid for a total of 35 GW by 2030[14].

Demand for power is at the inflection point where the combination of politics, economics, and regulations will accelerate growth beyond the capacity of the grid to reliably supply it.

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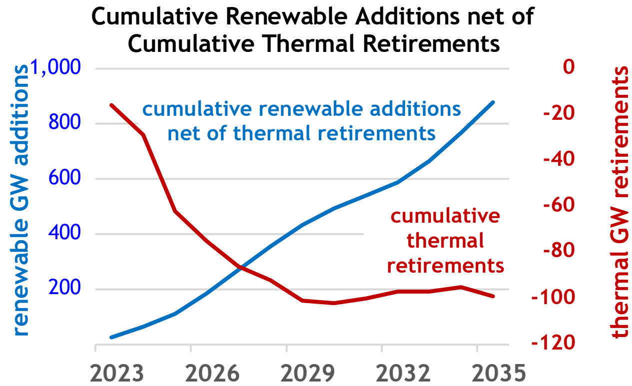
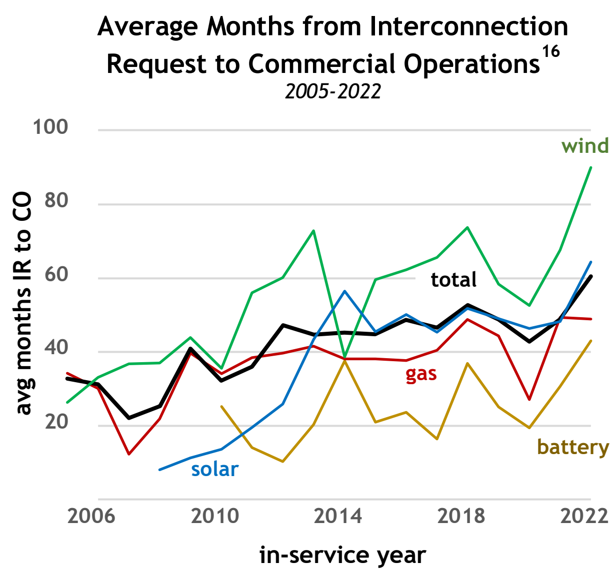
Growth In Power Supply Is Too Slow

The existing supply stack of the U.S. grid needs to change. A 100% carbon-free grid by 2035 will require the development of wind, solar, and battery power facilities faster than the retirement of the coal and natural gas plants they replace. New build development queues, however, are becoming longer while retirements of coal and gas-fired plants are accelerating.



Over the next 7 years retirements of thermal facilities are expected to more than quadruple and reduce thermal generating capacity by 12%, an estimate that continues to increase with new announcements of early retirements. Wind and solar additions over the same period are projected to more than double[15], but that forecast may appear optimistic with renewables construction facing increasing delays in development queues.

At the end of 2022 more than 10,100 projects were waiting for approval to connect to the grid, up from over 7,000 in 2021[16]. Only 21% of projects that filed Interconnection Requests from 2000 through 2017 began commercial operations before the end of 2022 after an average of 5 years in the development queue, up from 3 years in 2015 and under 2 years in 2008.



Renewable energy projects must pass a complex review process with detailed technical analysis, environmental assessments, and community engagement. Obstacles developers face include not only extensive technical requirements that can change before a permit to build can be issued, but also opposition from the public to local siting of power facilities.

The integration of renewable energy into the grid requires sufficient transmission infrastructure to transport electricity to urban areas from regions with prevailing sunny and windy conditions. Capacity constraints or delays in expansion of the grid can prevent interconnection of new renewable projects. In some cases, the local grid is operating at full capacity and cannot absorb more power when a project has completed the technical review[17].

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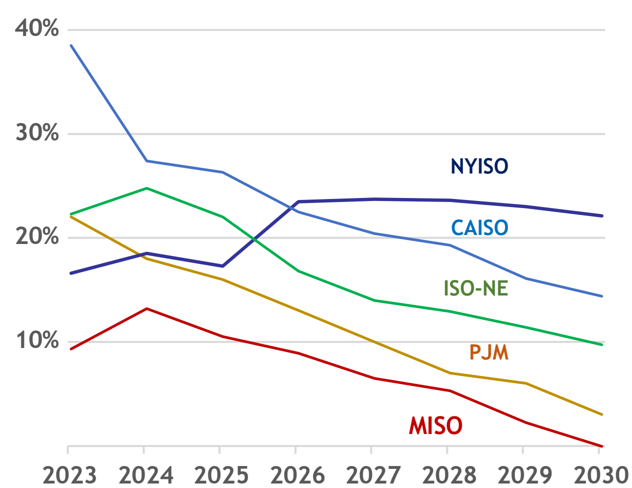
Perhaps the most significant issue, however, is the sheer volume of new projects, which exceed the capacity of the agencies and engineers to review and approve them. This is the natural outcome of the smaller size of renewable projects, which means more are required to replace the larger coal and gas-fired plants that are taken out of service. One wind or solar facility requires the same review process (and work) as a much larger coal or gas-fired plant. Delays and technical constraints of the grid often force developers to cancel their projects before construction begins. Between 2012 and 2022 over 8,700 interconnection requests were withdrawn or suspended from over 20,000 that were filed over that period.[16]

Stability of the Grid is Changing

Accelerating retirements of thermal facilities and a permitting process overwhelmed by the volume of new projects raise the specter of a grid unable to provide a reliable supply of power to meet future demands. To ensure reliability, utilities maintain reserve margins of excess generating capacity based on their history of maximum expected demand, which is now growing faster than capacity. As demand outpaces supply, reserve margins are projected to fall below prudent safety margin minimums. Shrinking reserve margins will weaken the capacity of the grid to accommodate short-term surges in demand and lead to higher and more volatile prices.[18]

Projected ISO Capacity Reserve Margins[18]

2023-2030



The replacement of baseload and dispatchable thermal power plants with renewables introduces another source of volatility for power prices. Transmission grids need to stay at a stable frequency to operate effectively. Large surges in power demand due to weather or equipment failure require a secure source of generation capacity that can be started up and placed online rapidly on a moment's notice to accommodate the excess demand and avoid blackouts and damage to equipment. Power generation facilities that can deliver power onto the grid and quickly respond to output changes as needed are called dispatchable and include predominantly gas and oil-fired facilities.

Baseline power generating facilities, which include coal and nuclear, are not dispatchable. They are slow to come online, only provide a static and non-variable source of power once online and cannot respond to changes in demand.

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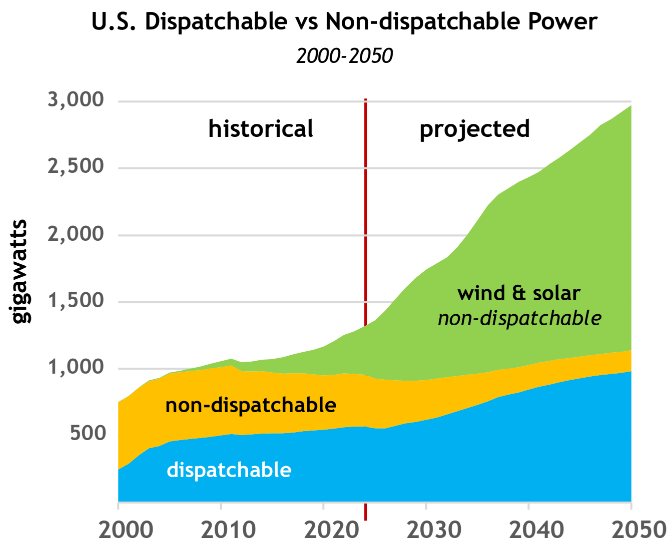
Wind and solar depend on wind and sun and are intermittent sources of power. The timing of when they come online, as well as the power they produce, is not controllable. Variations in output from local sun and wind conditions often create imbalances between supply and demand followed by fluctuations in power prices when markets respond to changing conditions. As renewables displace dispatchable and stable baseline power sources, supply of power available to meet surges in demand becomes more volatile, power prices become more volatile, and operators must raise prices to recoup their costs.



The impact of the technical limitations of renewable power on the grid is potentially huge. A recent study for the New England ISO System concluded that the reserve margin required to ensure reliability for an all-renewable grid would need to increase from 15% today to 300%. Any savings in carbon emissions would require significantly more capital per KwH and outsized onshore and offshore acreage for the necessary wind farms and solar fields[19].

The increasing importance of weather-dependent power sources in the grid will have a profound impact on power prices and the reliability of power supply. Power pricing will become more volatile[20], rolling blackouts more likely, and the cost of power more expensive as operators seek to recover capital and higher operating costs.

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