Clear Path to a Clean Energy Future 2021:
The Role of Utility Commitments on the Path to 2050

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CLEARPATH

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Executive Summary

America has greatly reduced emissions in the power sector over the last 15 years, yet as this report shows, the easy part is over and power sector emission reductions could flatline under current conditions. One bright spot is that some of America's largest publicly owned utilities and major American companies are taking action against climate change by pledging to further reduce carbon dioxide emissions by midcentury. These "net-zero commitments" may avoid the flatline but improved public policy is needed to help deploy clean, reliable, and affordable energy technologies to fully reach net zero.

Clear Path to a Clean Energy Future is a first-of-a-kind report that will be published annually to track the latest power sector trends and model future technology and policy impacts. This inaugural edition focuses on the role of electric utility decarbonization targets. The authors engaged Rhodium Group, a leading research firm that analyzes energy policy and climate risk, to model ClearPath-designed scenarios using RHG-NEMS, a version of the National Energy Modeling System created by the Energy Information Administration as modified and maintained by Rhodium Group. The analysis led to several key findings:

1. Carbon emissions in the power sector are expected to flatline after 2025, remaining at 96% of today's emissions in 2050, even with recently enacted federal incentives and state-level clean energy standards. Over the coming decades the exhaustion of economic coal-to-gas shifting, existing nuclear plant closures, and continued load growth in states without climate targets will lead to shallow decarbonization, creating a cul-de-sac effect.

2. This modeling found large electric utilities' decarbonization pledges, many of which are for net-zero emissions by 2050, will have a significant impact of avoiding this flatline. The scenario based on existing utility commitments reduced carbon emissions to 56 percent below 2005 levels in 2050—20 percent lower than the reference scenario.

3. However, the power sector will continue to emit over a gigaton of carbon emissions annually in 2050, a gap that must be overcome through new market-friendly policies and technology improvements to enable power companies to fully reach their goals. Lowering the cost of dispatchable clean energy technologies such as carbon capture, long-duration energy storage, or advanced nuclear, as well as flexible demand technologies could make it easier for utilities to reduce emissions faster, and for additional utilities to commit to net-zero emissions.

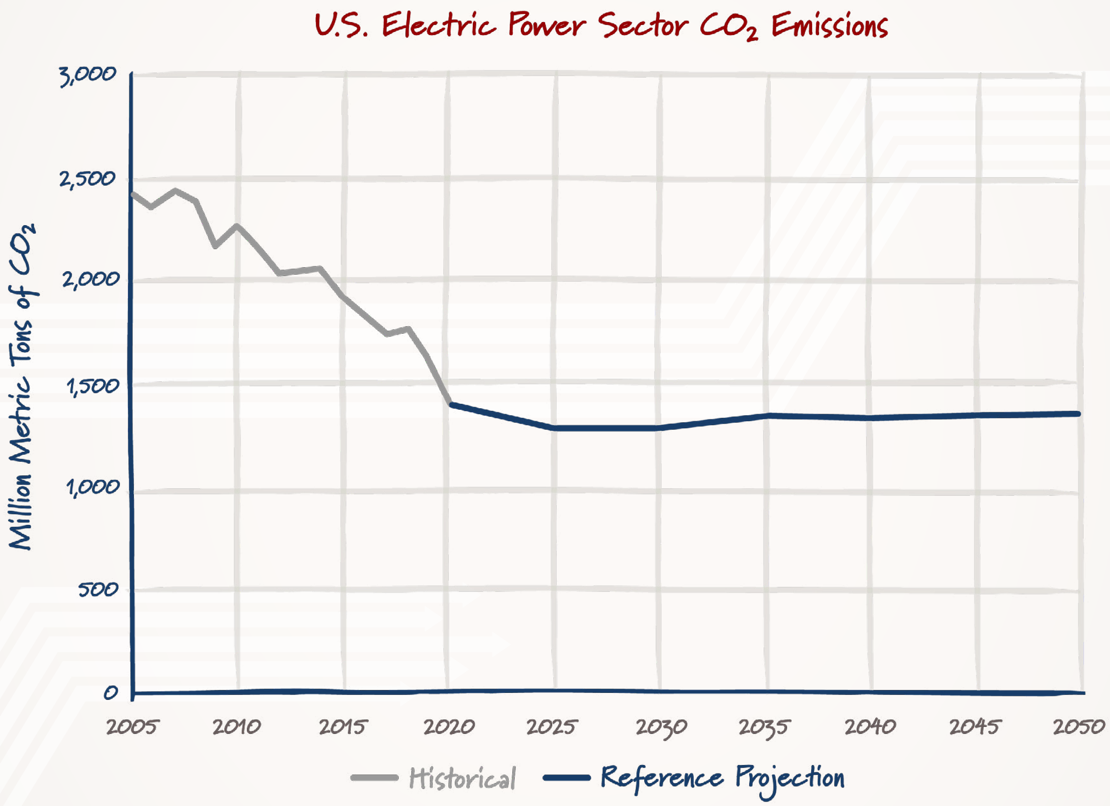
4. Maintaining existing nuclear reactors is one of the cheapest ways to help meet utility commitments and reduce carbon emissions. The utility commitments scenario preserved 22 gigawatts (GW) of nuclear that closed in the reference scenario.

5. Under current market dynamics, natural gas, solar, and wind technologies will be the vast majority of new generation under construction in the United States for the foreseeable future.

Main Takeaways

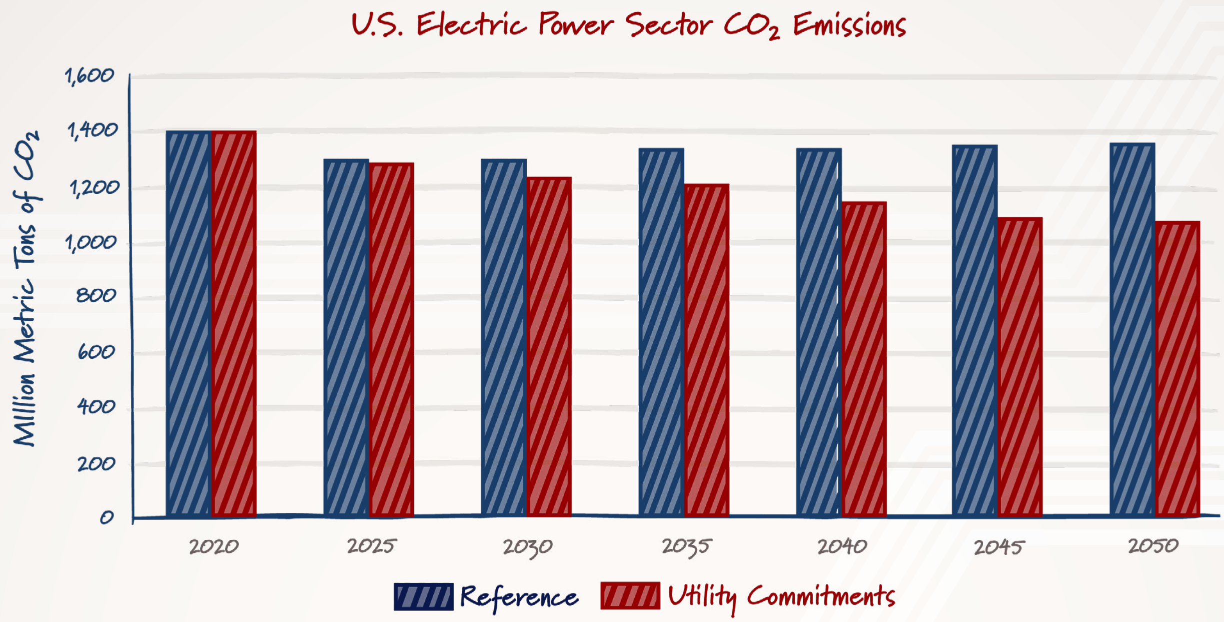
We Could Be Heading Toward an Emissions Cul-De-Sac

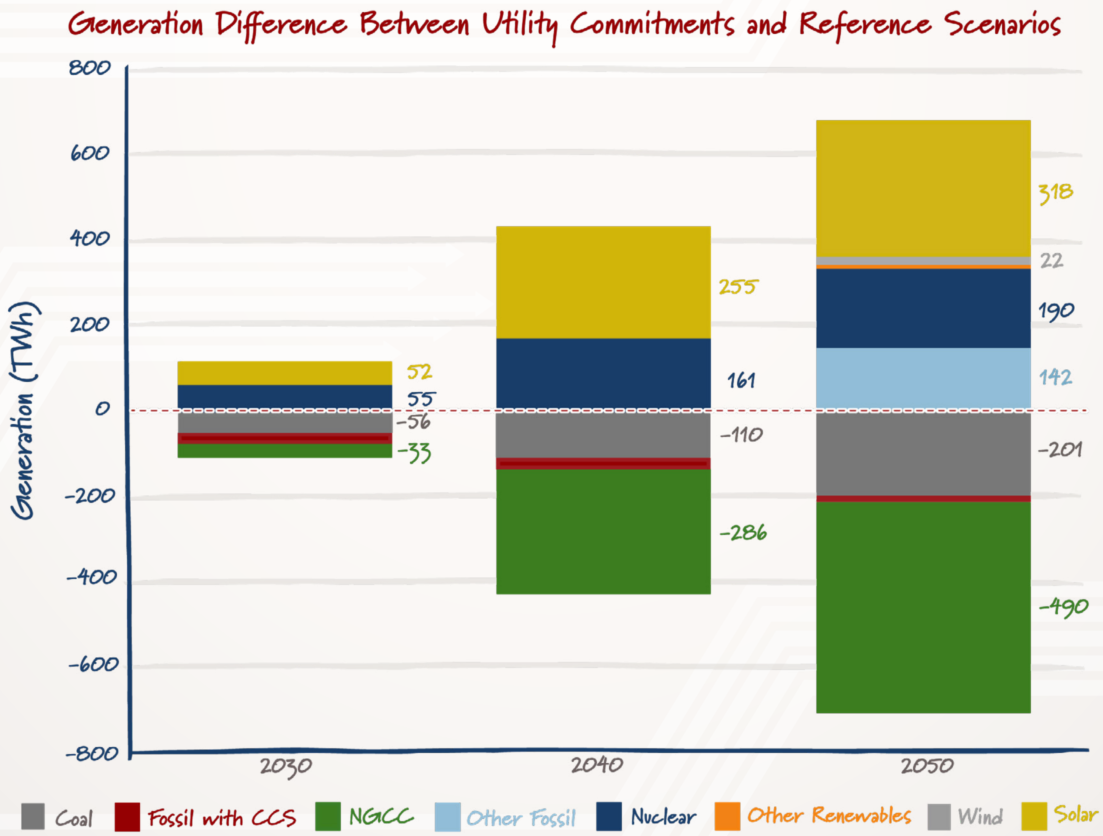
The last 15 years has seen a remarkable period of very low natural gas prices, decreasing costs and incentives for renewables, and economic downturns from the financial crisis and Covid-19. Collectively, this has driven a 40 percent reduction in electricity carbon emissions since the peak in 2005. However, this relatively easy decarbonization appears to be coming to an end. As a result of nearly all uneconomical coal being driven out of the market and projected nuclear reactor retirements, the reference scenario projects that carbon emissions will largely flatline after 2025 if natural gas prices stay low. The total of new natural gas generation emits more than the remaining economic coal reductions and also replaces non-emitting nuclear energy. This "cul-de-sac" in shallow decarbonization comes despite state-level clean energy policies, since load growth is accelerating in parts of the country without those policies in place.



Existing Utility Decarbonization Targets Have a Significant Impact

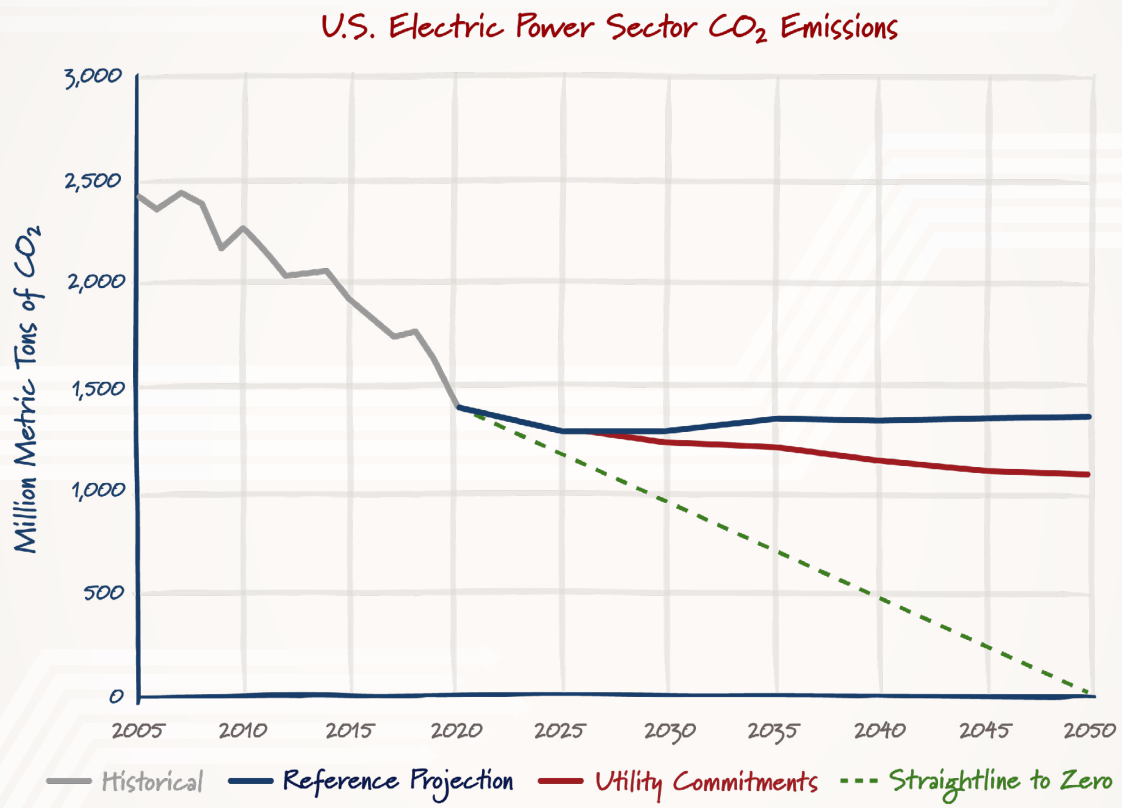
In late 2018, a number of large electric utilities began to make voluntary net-zero decarbonization commitments on a midcentury time horizon. Since then, a total of 51 utilities, representing 71 percent of customer accounts in the U.S., have established carbon-free or net-zero goals by 2050.[1] We modeled the electric utility decarbonization commitments in place as of October 2020 assuming investors hold them to those commitments, many of which are for net-zero emissions by 2050.[2] Utility decarbonization commitments have a nontrivial impact on carbon emissions and on solar and nuclear energy generation. With current utility commitments taken into account, emissions are projected to continue their decline rather than flatline, ultimately reaching 56 percent below 2005 levels by 2050. Additional solar, nuclear, and "other fossil"—essentially gas combustion turbine generation—comprise the biggest gains, offsetting large amounts of additional coal and combined cycle gas electricity.





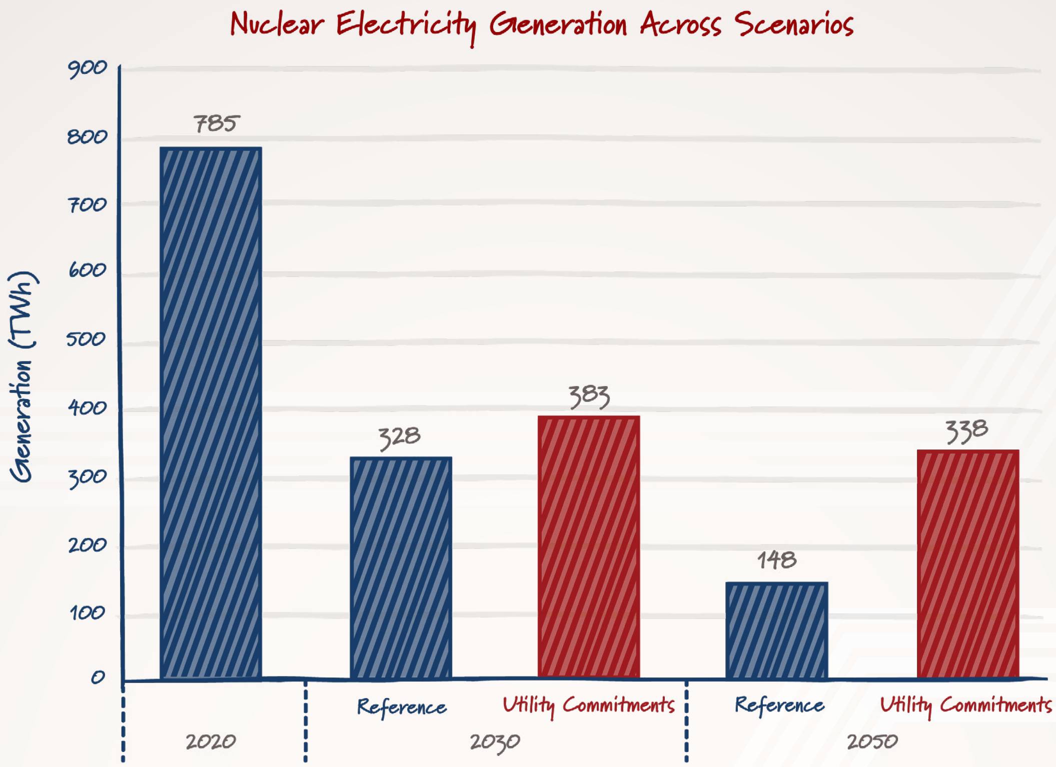
Large Emissions Gap Remains; Affordable Clean Dispatchable Tech Could Help

Even with existing state policies and utility decarbonization commitments, the U.S. is not heading toward net-zero power sector emissions by 2050. To do so would require annual emissions reductions to continue for the next 30 years at a similar rate as the last 15 years. Significant levels of natural gas combined cycle deployment continues through 2050 to ensure dispatchable capacity, despite the low cost of solar in the out years. Lowering the cost of dispatchable clean energy technologies such as carbon capture, long-duration energy storage, or advanced nuclear, as well as flexible-demand technologies could make it easier for utilities to affordably reduce emissions faster, and for additional utilities to commit to net-zero emissions. Public policy support is needed to further drive these costs down, making the technologies affordable and deployable for utilities and the customers they serve.

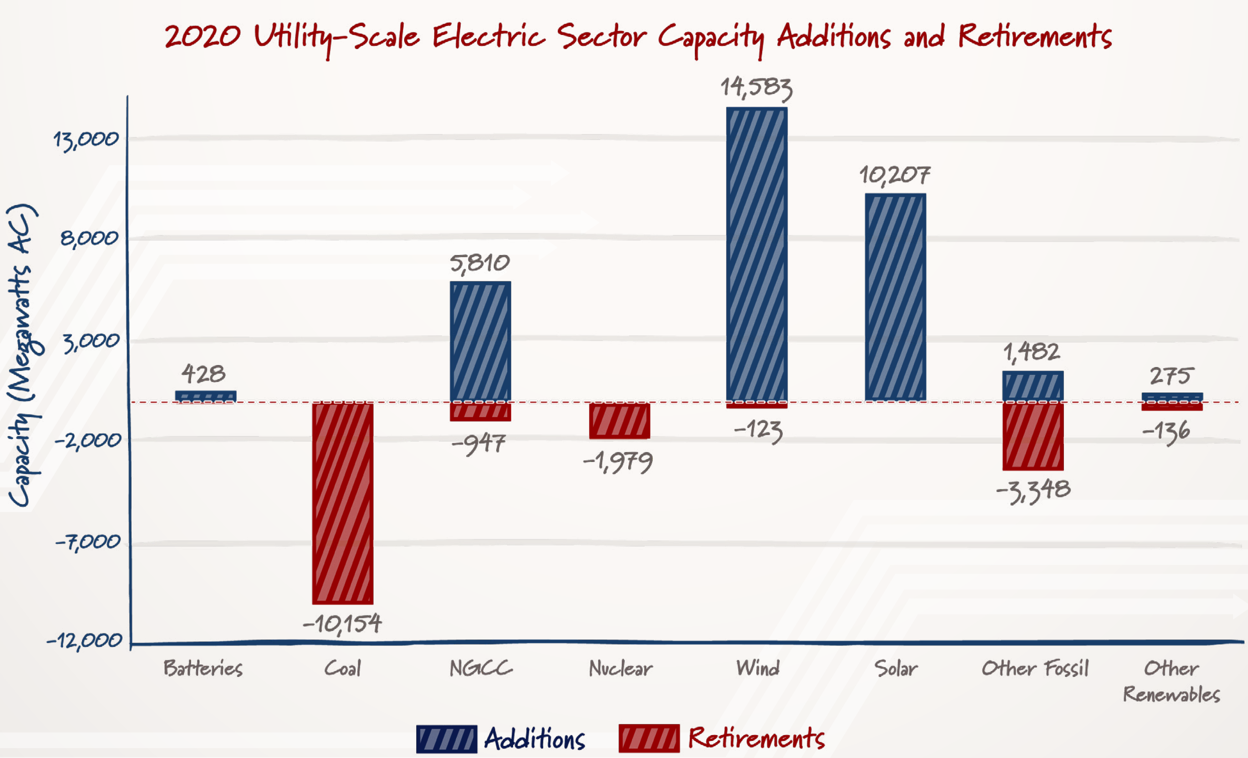


Existing Nuclear Is a Reliable and Affordable Way to Reach Utility Decarbonization Targets

In areas of the country with utility net-zero goals in place but no state-level clean energy policies, preserving existing nuclear plants is projected to be one of the most affordable ways to achieve those utilities' decarbonization goals. In the utility commitments scenario, 22 GW of nuclear power that would have closed are preserved, resulting in over twice as much nuclear-generated electricity in 2050. More companies establishing a net-zero commitment would likely lead to even more nuclear being preserved.



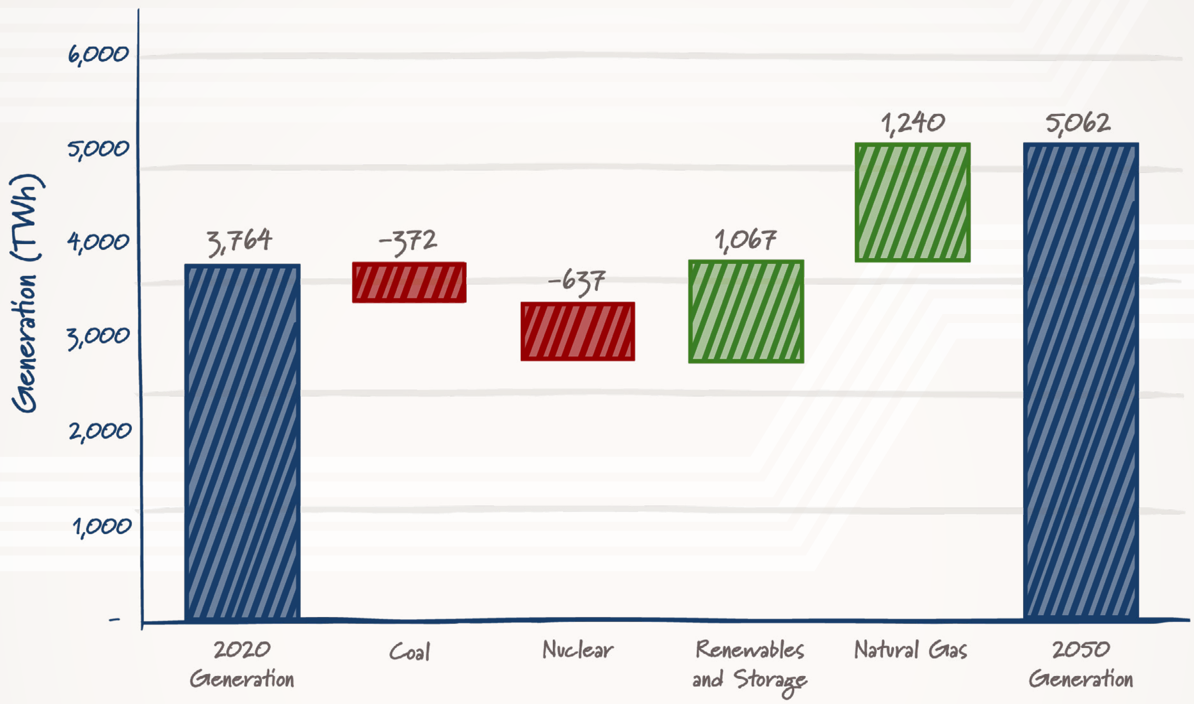
Market-Driven Shift in Power—Only New Gas, Solar, and Wind on Horizon
Capacity additions and retirements in 2020 are a sign of future trends. Twenty-five GW of wind and solar were added in 2020, along with a net addition of five GW of natural gas combined cycle capacity. Offsetting these additions was the retirement of 10 GW of coal and two GW of nuclear power.



Source: *U.S. EIA Form 860*

Our reference scenario projects that these trends will only continue, with significant coal and nuclear retirements, and most new generation coming from renewables and natural gas combined cycle.[3] Due to higher rates of operation (also known as the capacity factor), natural gas combined cycle ultimately adds more annual electricity generation by 2050 than renewable energy. Wind energy additions eventually peter off after the expiration of the wind tax credit (in 2021 for onshore wind and 2025 for offshore wind); however, solar continues to grow after the tax credit expiration, ultimately representing the vast majority of new renewable energy generation post-2035.

Major Changes in Generation between 2020 and 2050, Reference Scenario



Recommendations

A number of key actions could close the remaining electricity emissions gap of over one gigaton of CO_2e through 2050.

Additional Utilities Need Net-Zero Carbon Goals and Clear Action Plans

The analysis projects that individual utility decarbonization goals can add up to a significant impact if they are met. However, while much of the continental U.S. has its electricity supplied by utilities with net-zero goals, many of the areas with the fastest load growth have limited or no goals. For utilities with goals in place, clear action plans should be established in Integrated Resource Plans (IRP). If there are policy or technological advances needed to achieve the goal, those utilities should establish a scenario analysis to showcase the potential impact of various policy mechanisms or technology improvements. Retail utilities must also define their goals based on electricity delivered, rather than produced.

More Affordable Dispatchable Clean Energy Is Needed

There is general agreement that dispatchable clean energy will help lower costs in a net-zero electric grid; however, almost no new dispatchable clean energy was added in either scenario. More diverse affordable clean energy options could reduce the total capacity construction required to achieve decarbonization goals, reducing the cost of achieving those targets. Additionally, the vast majority of large utilities with net-zero goals have stated that new technologies will be required to reach those goals at scale. Programs to demonstrate cheaper dispatchable clean technologies and incentives to support early stage technologies can help reduce the cost of those technologies.

State and Federal Policy Is Still Needed to Support Existing Nuclear

This analysis demonstrates that extending the operation of nuclear power plants can be a cost-effective source of emissions reductions and that without action a majority of the nuclear fleet will become increasingly uneconomical over the next decade. State and federal support is warranted to avoid unnecessary retirements.

State and Federal Policy Is Still Needed to Support Existing Nuclear

There are a number of recent federal policy proposals that could help reduce the cost and timeline of decarbonizing the power sector. Some of the proposals with the greatest bipartisan support include:

1. Extending and Enhancing the 45Q Carbon Capture Credit
2. Preserving Existing Nuclear Plants for Climate Benefits
3. Funding Demonstration Projects Authorized in the Energy Act of 2020
4. Technology-Neutral Tax Incentives for Emerging Technologies
5. Improved Energy Technology Permitting Methods

Introduction: The Path to 2050

ClearPath's underlying thesis is that developing new and improved clean energy technologies is critical to affordably and rapidly reduce carbon emissions globally. Furthermore, we believe that the United States has a positive role to play by innovating affordable technology to reduce carbon emissions. In 2019 the U.S. represented only 11 percent of global greenhouse gas emissions,[4] a percentage that's likely to continue decreasing. The U.S. must continue to reduce emissions, but as every molecule of carbon dioxide has the same effect on warming, the ability to influence other nations through technology and policy development should be a major consideration.

This report is intended to serve as an annual baseline to track U.S. progress toward decarbonization in the power sector, including recent trends in federal and state policy and the energy sector more broadly. This initial installment assesses the role of utility decarbonization commitments made thus far. Future installments will focus on the role of new technologies and policies in accelerating clean energy deployment. This report distills energy and climate trends into guideposts and policy recommendations to chart a clear path forward.

This report is structured as follows:

- First, it provides an overview of energy and climate trends in the U.S. over the last year, including trends in emissions, electricity, utility decarbonization commitments, federal and state policy, and corporate clean energy.
- Second, the report covers a new set of energy sector modeling between now and 2050, which includes the first ever modeling of utility decarbonization targets, along with a reference scenario for comparison.
- Finally, the report covers the remaining emissions gap between existing decarbonization commitments and a net-zero power sector, along with policy recommendations to affordably accelerate emissions reductions.

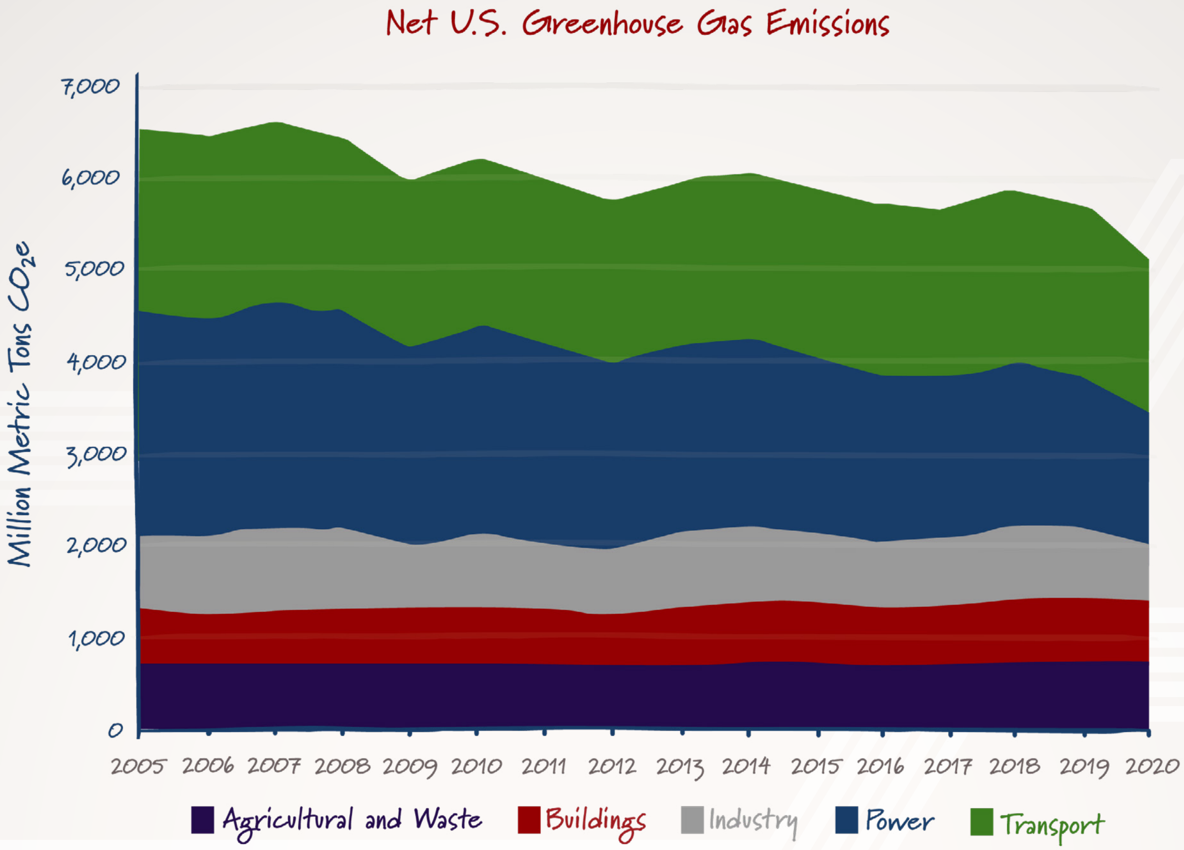
Where Are We Now? A 2020 Climate and Energy Review

The events of the last year, from Covid-19 to the grid issues in Texas and California, will reverberate through the energy system for years to come. There were significant changes in emissions and power sector deployments over the last year, many of which were overlooked due to the pandemic. In addition to energy sector trends, there were big federal and state policy developments regarding clean energy.

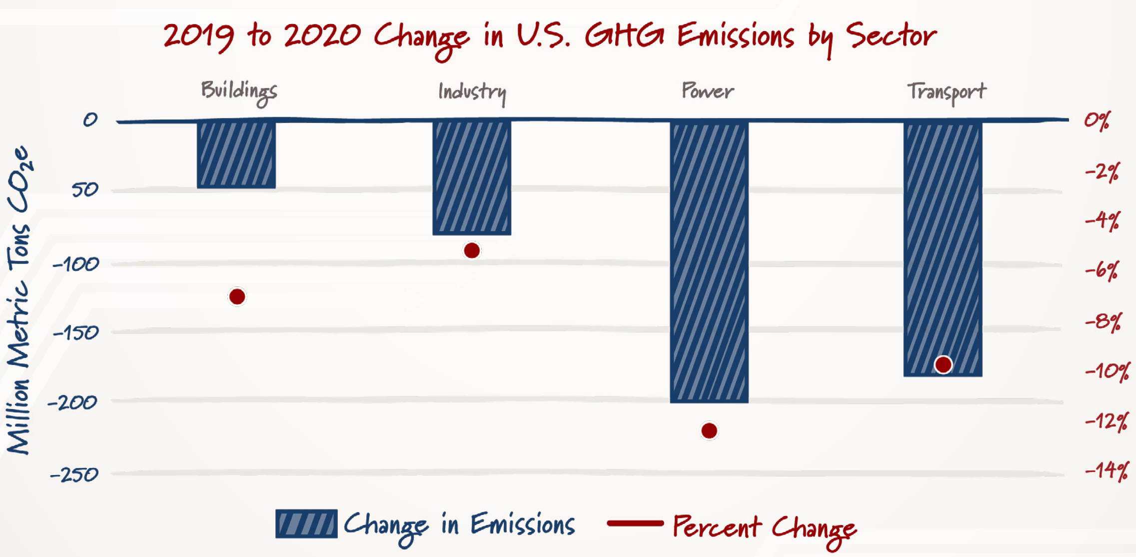
Emissions Trends in the U.S. Economy

Economy-wide U.S. greenhouse emissions declined 10.3 percent in 2020, setting a new record in the modern era.[5] Thus far, U.S. emissions have fallen 21.5 percent since 2005, well exceeding the 2009 Copenhagen accord goal of a 17 percent reduction by 2020. These emissions reductions have been driven by reductions in the power sector, where emissions have dropped 40 percent since 2005. This success has been spurred on by the tremendous cost declines in both natural gas and renewable energy technologies. At the same time, it is clear that the dramatic drop in carbon emissions in 2020 came at a tremendous cost to both public health and the U.S. economy. Globally, it is expected that emissions in 2020 will represent an eight percent reduction compared to 2019, twice as large as all other reductions since WWII—combined.[6] In 2021 it is also expected that emissions will rebound somewhat as the economy recovers.

In addition, emissions from the transportation sector fell, while industrial sector emissions remained flat. For the first time, the industrial sector emitted more than the power sector—a trend unlikely to reverse anytime soon.[7]



Source: Rhodium Group *ClimateDeck*



Carbon emissions are likely to rebound somewhat in 2021, but they will remain below pre-Covid levels. It is expected that as the economy improves, so will carbon emissions. This is not a bad thing, as lowering emissions should not be conflated with lowering economic growth. In fact, over the last decade, the rate of emissions per GDP has declined dramatically as economic growth has decoupled from energy use and as the energy sector has grown cleaner.[8]

As stated, for the first time, industrial sector emissions were higher than power sector emissions. However, without new technologies industrial sector emissions are expected to increase quicker than all other sectors over the next decade. In fact, by the end of the decade, the industrial sector will likely represent the largest source of emissions in the United States, something that would have been extremely surprising until recently. This trend is why ClearPath recently expanded its portfolio to include clean industrial technologies. The ability to manufacture and build affordably and cleanly will be essential to continue economic growth while reducing emissions.

Overall, carbon emissions trends in the United States have demonstrated the ability to reduce emissions through a combination of technological improvement and clean energy tax incentives. With continued investment in clean technologies, it is likely that emissions will continue to decline. That said, the United States is not on track to achieve net-zero emissions by 2050, which the global electric sector must reach to have a high likelihood of limiting the worst impacts of climate change.[9] Doing so would require additional policy and improvements in technology.

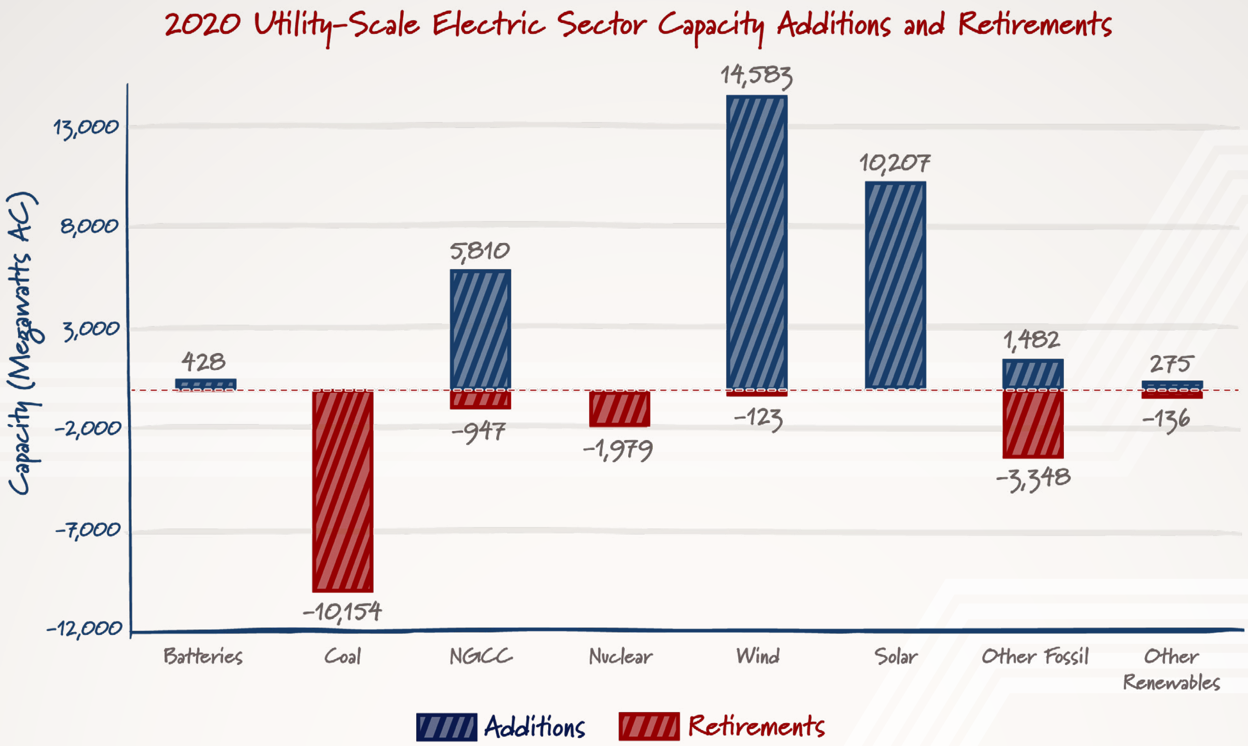
Power Sector Trends

The impact of the Covid-19 pandemic had significant impacts on the ways Americans use energy, both in the transportation and power sectors. The drop in demand coupled with large increases in renewable energy capacity led to a 10 percent reduction in electricity emissions, far steeper than the three percent reduction in demand.[10]

Coal-powered electricity generation fell nearly 20 percent in 2020, which was the greatest decrease of the year and the largest contributor to reduced emissions. This large decline in generation was due to both retirements and fewer hours of operation. The average coal plant capacity factor fell seven percentage points in 2020, with coal plants only operating 40 percent of the time.[11] EIA's short-term energy outlook predicts coal generation will recover in 2021 and 2022, but it is unlikely to return to 2019 levels.[12] Generation from natural gas combined cycle increased about two percent in 2020, and added just under five gigawatts in new generating capacity.

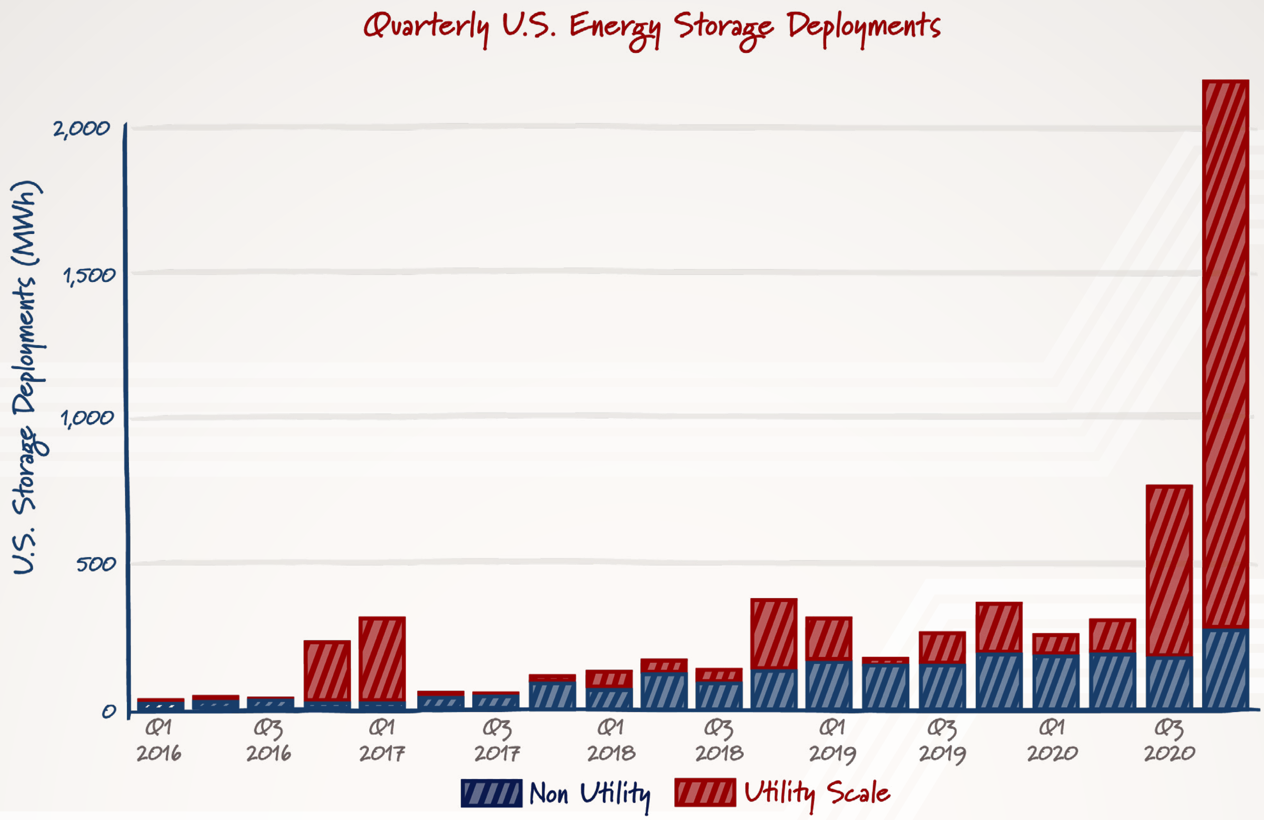
As a result of this large reduction in generation, coal was the third largest source of electricity generation in 2020, behind nuclear energy for the first time in history. However, as nuclear plants represent over half of planned retirements in 2021 and coal generation is expected to increase, this was a temporary blip.

Solar and wind energy grew significantly in 2020. Both the solar and wind energy industries set new records for annual utility-scale installations with over 14 and 10 gigawatts of capacity, respectively. This 14 gigawatts of wind energy construction also represented the largest amount of capacity installed in 2020. Meanwhile, overall solar energy generation grew by a whopping 35 percent year over year, and wind energy generation grew by four percent.[13]



Source: *U.S. EIA Form 860*

Utility-scale energy storage also finally took off in 2020. In total, over 3.5 GWh of energy storage was deployed in 2020, which was more than the previous six years combined.[14] This represents exponential growth. Much of this increase was dominated by several very large battery projects, and future projects of this scale are not under development. Two-thirds of the new energy storage deployment was in California, due to that state's high solar penetration (26.4 percent in 2020), as well as state-level energy storage targets. Solar now represents nearly all power generated during the middle of a sunny day in California, and because solar energy's marginal operating cost is close to zero, that drives the price of electricity close to zero as well. Therefore, the realized price for solar electricity in California in 2020 was nearly 30 percent lower than for a generation facility that ran all the time, and as more solar is added, that capacity is increasingly worthless without some type of storage capacity that can hold and redeploy that electricity when there's higher market demand.[15] These megabatteries are expected to shift solar power into the evening, when it is more valuable.



Source: Wood Mackenzie *Energy Storage Monitor*

Recent Federal Policy Updates

2020 was the most significant year for clean energy and climate policy in well over a decade. The Consolidated Appropriations Act of 2021, enacted at the end of 2020, included four crucial pieces of climate and clean energy legislation: the Energy Act of 2020, the phaseout of hydrofluorocarbon pollutants, an extension of clean energy tax credits, and record appropriations for energy R&D programs at DOE. Taken together, these policy initiatives provide a bipartisan blueprint to guide administrative action on clean energy and climate, particularly with regards to energy innovation.

Energy Act of 2020

The Energy Act of 2020, included as Division Z of the Consolidated Appropriations Act,[16] is the first comprehensive energy authorization law to be enacted in 13 years. It represents dozens of individual bills from many members of both parties in both the House and Senate, such as the Nuclear Energy Leadership Act, the Better Energy Storage Technology Act, and the Advanced Geothermal Innovation Leadership Act.

The Energy Act includes 11 titles, with subjects ranging from energy efficiency to renewables and storage, critical minerals, and beyond. It is heavily focused on reauthorizing energy research, development, and, perhaps most significantly, demonstration programs that are crucial for decarbonization. In total the law authorizes over 20 large clean energy demonstrations over seven years. The graphic below highlights some of the most important provisions of the Energy Act:

Key Energy Technology Programs in the Energy Act of 2020

Tech	Description
Title II: Nuclear	• Formally authorizes Advanced Reactor Demonstration Program • Creates High Assay Low Enriched Uranium fuel availability program for advanced reactors • Facilitates collaboration between the private sector and national labs to work on fusion technologies • Establishes a milestone-based development program for fusion energy concepts
Title III: Renewables and Storage	• Significant reauthorizations of R&D for all renewable power and energy storage technologies • Improves the development of renewable energy on public lands • Overhauls programs for solar, wind, water, and geothermal energy to focus on the most pressing challenges • Reorients the federal gridscale storage research, development, and demonstration program around ambitious technology goals necessary to facilitate breakthroughs necessary for grids of the future
Title IV: Carbon Management	• Reorients the Office of Fossil Energy to focus on carbon capture, utilization, and storage technologies • Authorizes a comprehensive carbon capture R&D program focusing on first of a kind and follow-on carbon capture demonstrations for natural gas, coal, and industrial facilities • Authorizes research for carbon utilization and storage to ensure captured carbon can be efficiently prevented from entering the atmosphere
Title V: Carbon Removal	• Authorizes the very first comprehensive, crosscutting carbon dioxide removal research and development program at the DOE • Authorizes DAC testing centers and a prize competition for both pre-commercial and commercial DAC technologies
Title VI: Industrial Emissions	• Establishes crosscutting research and development, and a demonstration program for low-emission industrial energy technologies
Title X: ARPA-E	• Reauthorizes the Advanced Research Projects Agency Energy, a DOE agency that uses out-of-the-box program management to support emerging technologies through 2025, with authorization escalating up to $750 million per year

Elsewhere in the law, the Energy Act establishes additional programs and reforms in areas including energy efficiency, technology transfer, critical minerals policy, and the Loan Programs Office.[17]

Clean Energy Tax Extensions

45Q: The 2021 Appropriations Act included a two-year extension for the 45Q carbon capture tax credit, one of the largest climate actions included in the end-of-year bill. The 45Q tax credit was enacted in its current form in 2018 and provides $35 per metric ton of carbon dioxide utilized in products or enhanced oil recovery, or $50 per ton of CO2 sequestered. When initially passed in 2018, the 45Q credit required projects to commence construction before the end of 2023 to qualify. However, the Treasury Department took over two years to finalize regulations governing the use of the credit, which delayed many companies' efforts to develop projects before the 2023 deadline. The two-year extension in the Appropriations Act allows any project that commences construction by the end of 2025 to qualify, giving developers enough time to utilize the credit.

This two-year extension of 45Q is expected to single-handedly result in an additional 53 to 113 million tons of capture capacity, which corresponds to an additional 342 million to 585 million tons of avoided carbon emissions over the next 15 years.[18]

Renewable Tax Credits: The Appropriations Act also includes an extension for the Investment Tax Credit (ITC) and the Production Tax Credit (PTC), which support renewable energy development. Most importantly, for offshore wind technologies, the ITC was extended for five years, guaranteeing a 30 percent tax credit on capital costs for facilities that begin construction between now and the start of 2026. In addition to the offshore wind credit, the ITC was extended by an additional two years, and the PTC was extended by an additional year. Solar energy, fuel cell, small wind, geothermal, and offshore wind qualify for the ITC at various levels, while onshore wind, geothermal, closed-loop biomass, and hydropower qualify for the PTC at various levels.[19]

Utility, State, and Corporate Clean Electricity Commitments

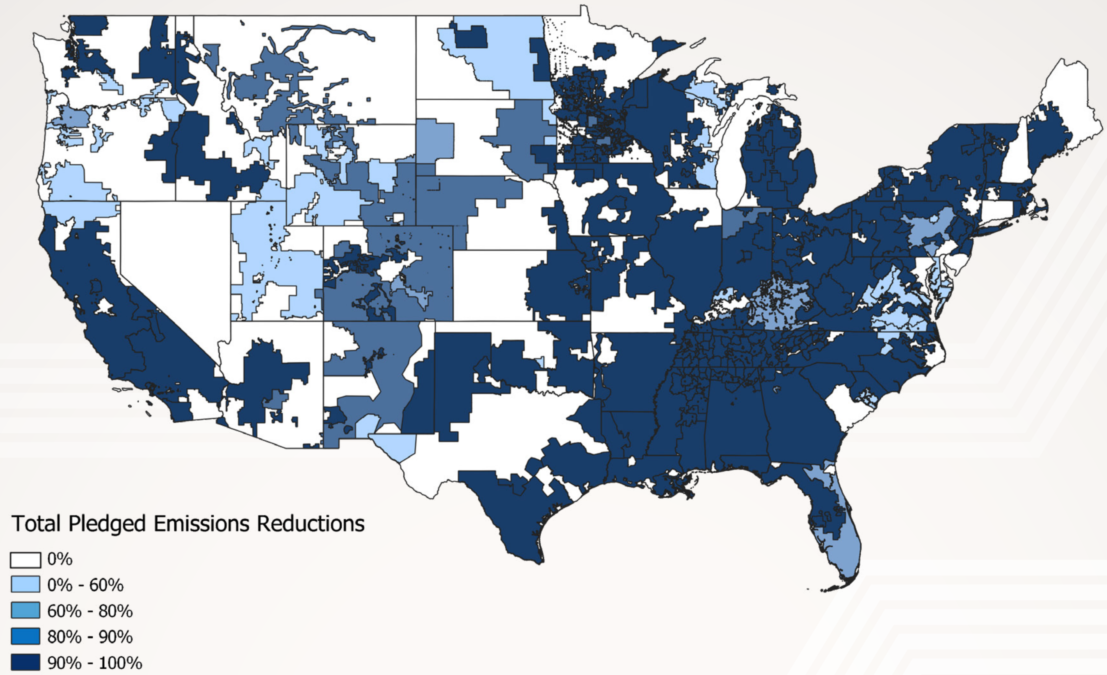
Numerous states, utilities, and corporations have set ambitious clean energy goals for the electric sector over the last two years, heralding a new wave of local and private sector action. These sub-federal actions can be major drivers to advance technologies and reduce emissions.

Utility Decarbonization Commitments

Some of the biggest advances in climate over the last year have been from electric utility commitments. At the time of writing, 51 electric utilities in the United States have made carbon-free or net-zero emissions targets, and over 70 percent of customer accounts in the country are supplied by an electric utility with a significant emissions reduction goal.[20] The map on the next page combines targets sourced from the Smart Electric Power Alliance with retail utility service areas to demonstrate which portions of the country have the most ambitious climate targets.

These decarbonization commitments have been primarily driven by the low cost of renewable energy, but most of the utilities making these pledges have also stated that reaching such ambitious goals will require significant technology and policy advances.

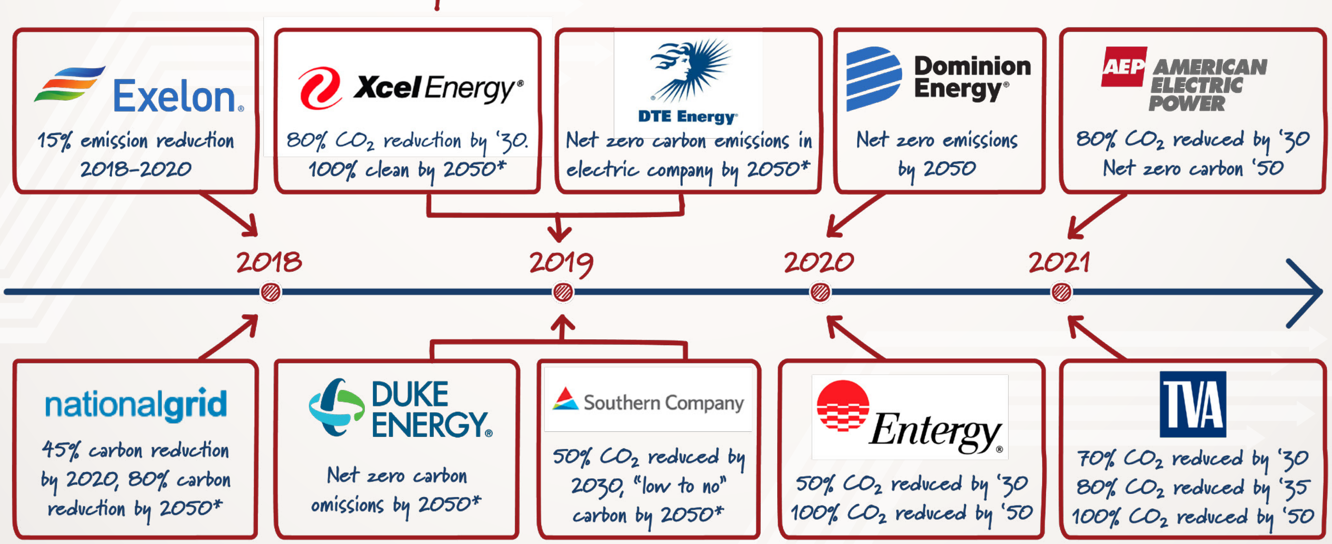
Utility Decarbonization Targets



Source: Commitments from SEPA *Utility Carbon Reduction Tracker*, service territories from *HIFLD* shapefiles.

Over 70 percent of utilities that have decarbonization goals of 80 percent or more explicitly state in their planning documents that new technologies are necessary to meet their goals. Within larger investor-owned utilities that have decarbonization goals, that percentage climbs to 84 percent.[21] The most commonly cited technologies necessary to achieve ambitious climate goals were demand-response capability to offset low generation availability, longer duration energy storage options, and dispatchable low-emission resources such as carbon capture or advanced nuclear.

Utility Decarbonization Commitments



*Indicates new technology is required to achieve commitments

Xcel Energy has among the most ambitious climate goals in the industry: 80 percent clean by 2030 and 100 percent clean by 2050. They have said that, even with their first-rate access to wind and sun, existing technology is sufficient to reach only 80 percent—not 100 percent—clean:

> *"We need a suite of new, carbon-free resources that can be dispatched to complement our continued adoption of renewable energy, energy efficiency and demand response. Our research shows that these new resources will be the key to achieving a carbon-free generation fleet without a costly overbuilding of the energy grid…These technologies may include carbon capture and storage, power to gas, seasonal energy storage, advanced nuclear or small modular reactors, deep rock geothermal and others not yet imagined."* [22]

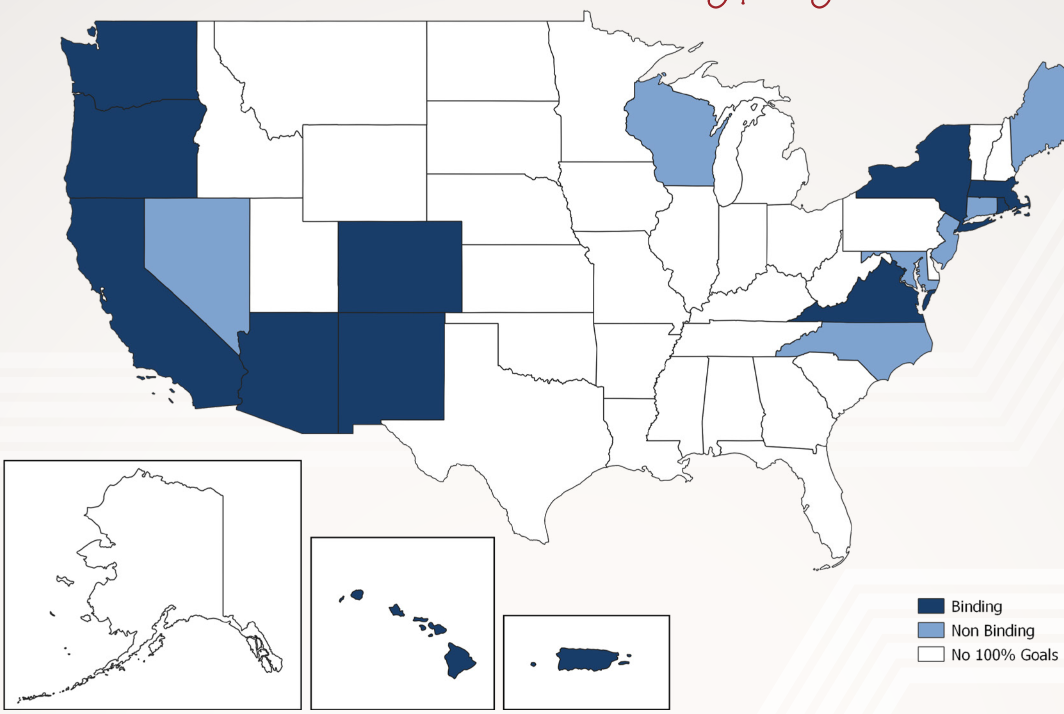
Without at least one of these new technologies reaching wide availability, or a significant buildout of interstate transmission capacity to move solar and wind energy across long distances from high-resource areas to high-load areas, the cost of reaching a zero-emissions electricity system would be extremely expensive, as solar and wind resources would need to be overbuilt to account for periods with low resource availability.[23] Many utilities also noted in their plans that if new technologies are developed relatively quickly, they could accelerate their decarbonization timelines further. One additional trend to note is that while many of these utility decarbonization targets have been made in response to state-level climate and clean energy laws, many of the net-zero targets have been set by utilities with a footprint entirely in states with no significant climate policy (these utilities include Duke Energy and Southern Company). Edison Electric Institute (EEI), the trade association representing investor-owned utilities, has also indicated its support for a national 100 percent clean electricity standard for 2050.[24]

EEI has created the Carbon-Free Technology Initiative (CFTI) to support federal policies that will ensure dispatchable clean energy technology by the 2030s.[25] CFTI is operated in conjunction with a number of nonprofit organizations to advance critical clean energy technologies, including advanced wind and solar energy; long-duration storage and advanced demand efficiency; super hot rock deep geothermal energy; zero-carbon fuels; advanced nuclear energy; and carbon capture, utilization, and storage.

State Clean Energy and Climate Targets

Numerous states have begun enacting ambitious clean energy goals, either through the legislature or state regulatory bodies. As of June 2021, nine states, Washington, D.C., and Puerto Rico have mandatory targets of 100 percent clean electricity, most of which come into effect in 2040 or 2050. In addition to these binding commitments, another nine states have non-binding goals set by governors or legislatures. The vast majority of these commitments are based on low-emission electricity technologies including renewables, nuclear, or carbon capture, except for Hawaii, Maine, Puerto Rico, and D.C., which have 100 percent renewable electricity requirements.

States with 100 Percent Clean Energy Targets in Place



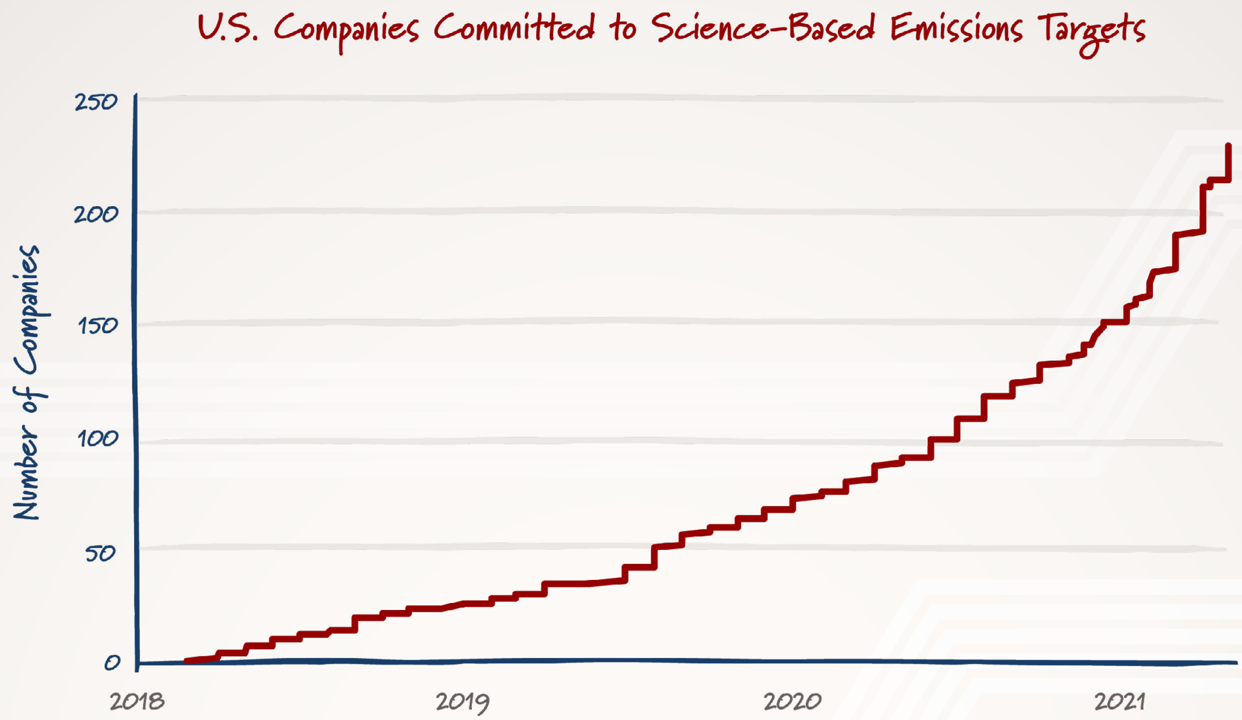
States with 100 percent clean energy goals represent 33.5 percent of total electricity consumption in the U.S., while over 22.3 percent of electricity consumption falls under a binding goal.

In addition to the states listed above, other states have carbon emissions reduction goals and requirements. Eleven states and Puerto Rico have enacted binding economy-wide emissions reduction targets. Emissions reduction targets are listed in Appendix B.

Corporate Clean Energy and Climate Trends

In addition to individual utilities pledging to reduce their emissions, many other large corporations have enacted their own pledges to significantly reduce emissions, both by reducing their own direct emissions and by reducing indirect emissions through the purchase of heat, power, and fuels. These companies demonstrate the role individual businesses can play in reducing emissions.

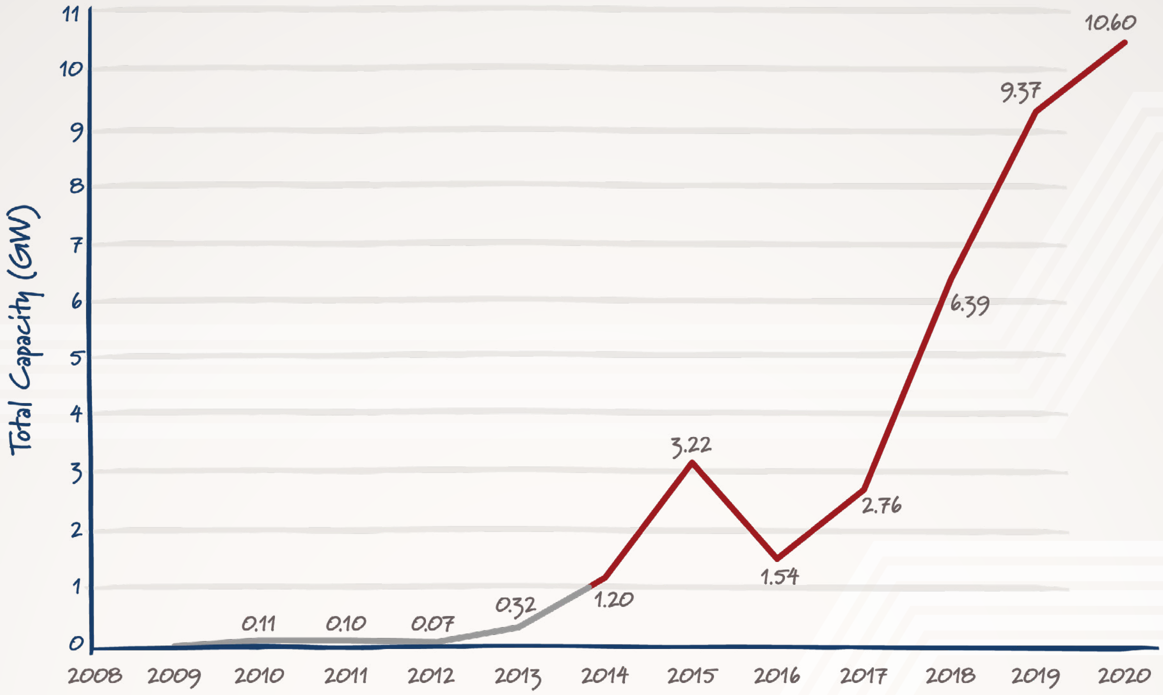
While it can be difficult to keep track and quantify the relative rate of emissions reduction activities by businesses, the number of businesses working with the Science-Based Targets Initiative (SBTI) can be a useful proxy for the rate of acceleration in this field. SBTI is a collaboration between the United Nations and several global nonprofits to support companies in setting carbon emissions reduction targets and associated implementation plans to minimize the impacts of climate change. The number of companies committed to reducing their emissions has grown significantly over the last three years, with nearly 250 committed companies in the United States alone.[26]



Source: *Science Based Targets*

When U.S. based SBTI participants are combined with utilities' decarbonization commitments, over 20 percent of U.S. companies with significant carbon emissions have now committed to a science-based reduction target.[27] These emissions targets are not meaningless. Over the last five years, emissions from companies working with SBTI decreased over 25 percent, while overall energy-related emissions increased by over three percent.[28]

In addition to establishing targets, large corporate energy users have also greatly expanded their procurement of renewable energy capacity. 2020 represented a new record for corporate power purchase agreements with a total of 10.6 gigawatts of new contracted capacity for renewable energy.[29] This new capacity, which will not come online for several years, is equivalent to 40 percent of the renewable capacity that came online in 2020, demonstrating that corporate procurement is a major driver of clean energy development. This level is also 13 percent higher than deals contracted in 2019, demonstrating the resilience of corporate procurement despite the impact of Covid-19. The graph on the next page, adapted from the Renewable Energy Buyers Alliance, shows this growth in procurement over time.



Source: *REBA Deal Tracker*

One company to highlight is Google, which has made a point of ensuring that all of its electricity—24 hours a day, seven days a week—will be supplied by clean energy by 2030.[30] There is a sizable difference between Google and other companies that have made commitments to procure 100 percent renewable energy. Most traditional renewable energy procurement is conducted by developing renewable energy projects to generate electricity equivalent to the company's consumption. However, in most cases companies that have procured renewable energy are still actually using electricity from the grid for their operations; their facilities are not solely running on renewable energy. In many cases the renewable facilities are located nowhere near the company's facilities and are sometimes as far away as other countries.

Switching to 24/7 clean energy means ensuring the electricity consumed at every single hour is matched by clean energy demand. Doing so requires a balance of clean energy resources, including standard solar and wind, as well as long-duration energy storage, geothermal, and potentially other carbon-free sources.[31] This approach recognizes that moving toward a net-zero electric grid will require resources to be available all year long at every hour.

Other companies are working to offset their carbon emissions by procuring carbon removal services. Carbon dioxide removal (CDR) is any process that captures carbon dioxide from the air or ocean and then sequesters it in such a way that it is not re-emitted to the atmosphere. The most common example of this is tree-planting or afforestation; however, many other techniques are being developed that are more technological, and therefore easier to measure and verify than purely natural means.[32] Utilities with limited renewable energy resources or carbon sequestration potential may need to procure carbon dioxide removal, such as direct air carbon, to offset a small portion of emissions and reach net-zero emissions.[33] The availability of affordable CDR technologies will make net-zero targets more achievable.

As affordable clean energy options continue to grow, it is likely that additional companies will develop science-based carbon targets and demonstrate private sector leadership.

What Does the Future Hold for the Power Sector?

As utilities make emissions reductions pledges and the cost of clean energy technologies continues to decline, clean energy will likely become an increasingly large share of the United States electricity mix. To benchmark clean energy progress, we engaged Rhodium Group to model two future scenarios of the U.S. power sector using RHG-NEMS, a version of the National Energy Modeling System (NEMS), developed by the Energy Information Administration (EIA) and commonly used to analyze the impact of various policies in the U.S. energy sector, that is modified and maintained by Rhodium Group. ClearPath designed two scenarios for the U.S. electric power sector through 2050, one of which is a new utility commitments scenario demonstrating the value of recent net-zero commitments if they are fully realized. For comparison purposes, we also designed a standard reference scenario similar to that used by the EIA's Annual Energy Outlook. Future versions of this report will track new utility commitments along with federal and state policies and their impact on the U.S. power sector.

Modeling Assumptions and Caveats

Rhodium Group modeled these scenarios with ClearPath's specifications using RHG-NEMS, a version of the National Energy Modeling System developed by the Energy Information Administration and maintained and modified by Rhodium Group. NEMS is a complex energy-economy modeling system for the United States. NEMS projects the production, imports, exports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics.

Two scenarios were modeled, one approximating the long-term operation and capacity expansion of the United States power sector through 2050 under current conditions (the "reference" scenario), and one treating recent decarbonization commitments by U.S. electric utilities as limits on emissions (the "utility commitments" or "UC" scenario).

Assumptions, unless otherwise noted below, were aligned with the V-shaped macroeconomic recovery estimates in Rhodium's Taking Stock 2020 Technical Appendix.[34]

Both scenarios include representations of most significant federal and state policies in place as of June 2020, such as federal and state renewable energy and nuclear tax incentives; state and regional cap-and-trade programs, Renewable Portfolio Standards (RPS), Clean Energy Standards (CES), fuel standards, and zero-emission credit programs. State storage and offshore wind mandates are also included, as well as clean energy tax credit extensions enacted in December of 2020.

Solar, wind, and energy storage cost assumptions are in line with Rhodium's Taking Stock 2020, based on the National Renewable Energy Laboratory's (NREL) Annual Technology Baseline. Henry Hub natural gas prices were assumed to start at $2.31/mmBTU in 2020 and rise to $2.51/mmBTU in 2050. For carbon capture, both scenarios included estimates of low cost direct-fired supercritical CO2 gas plant technology beginning in 2026 and low-cost staged, pressurized oxy-combustion (SPOC) coal plants beginning in 2031. Scenarios also included low-cost small modular reactors as a technology.

As with any large scale energy and economic model's projections, there are a number of important caveats to keep in mind when discussing modeling results. These results represent a projection of current market trends over time in line with federal and state policies on the books today. If policies, energy prices, technology costs, or consumption patterns change, reality will deviate from these projections.

While the NEMS model solves for basic reliability and policy constraints such as utility carbon caps, in many ways it does so coarsely. it does not fully represent dispatch of the electric grid for a large port of hours in a year.[35] This lack of granularity could potentially both overstate the level of firm capacity deployed, while also inaccurately representing variable renewable energy operation throughout the year.

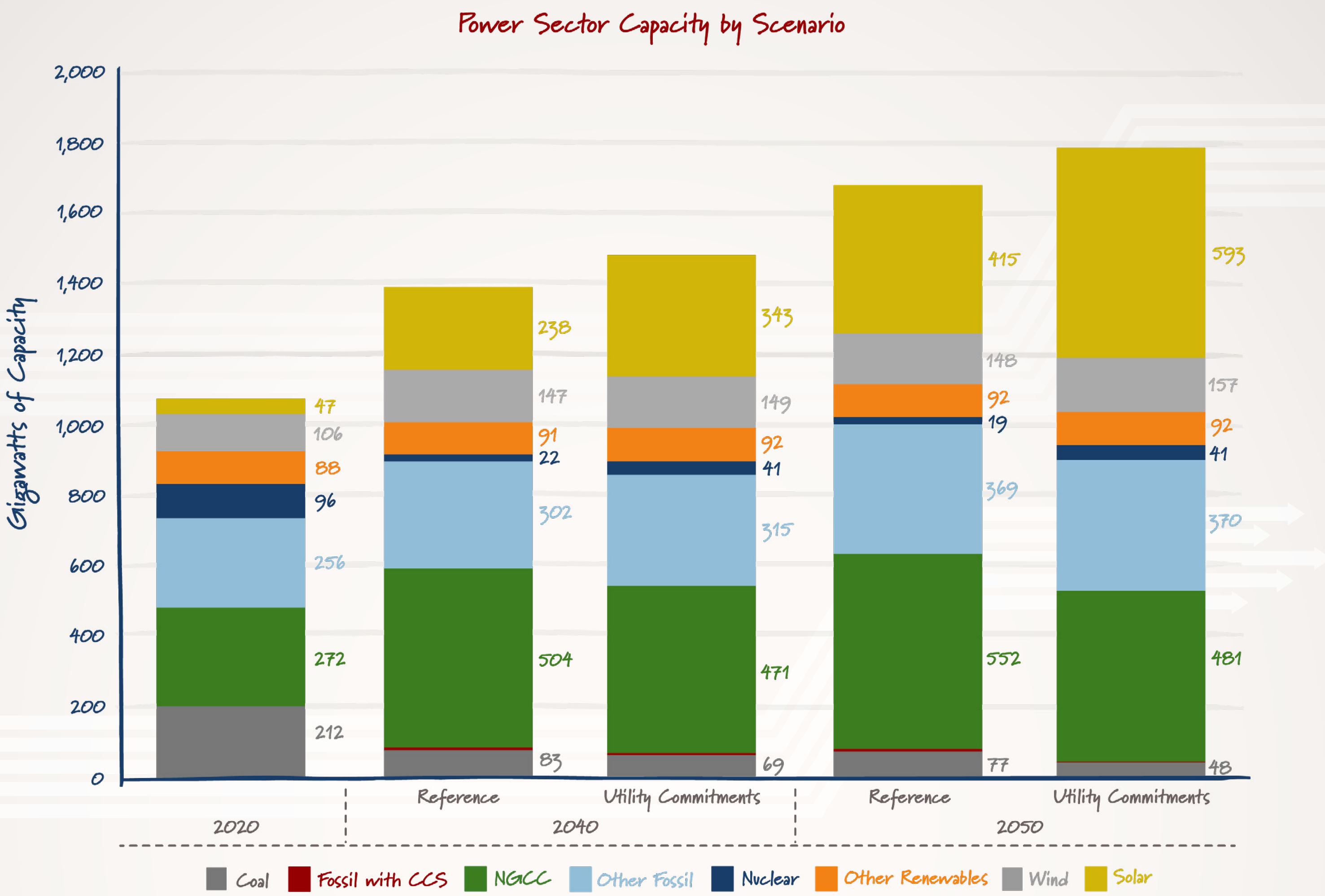
The way this particular analysis was conducted was at the national level, meaning that subnational or state trends are difficult to disaggregate. Subnational changes in energy technology deployment, emissions, and prices are estimated by the model, but all results were prepared only at the national level. For the utility commitments scenario in particular, it's important to note that utilities are able to source electricity from outside their service territories if it is economical to meet their respective carbon caps.

Additionally, the model deploys energy technologies in a techno-economically efficient manner, and cannot account for future social or political factors. It is not possible to fully represent the future ability to deploy energy capacity at the scale projected by the model, or in the locations in which capacity is built. Other factors, such as supply chain limitations, permitting challenges, or legal challenges could limit future deployment. For example, it may be economically efficient in the model to build transmission lines between the Southeast and the Midwest to import renewable energy, but efforts to build such infrastructure in reality have historically failed.

Current Electricity Trends Through 2050

Power sector capacity is projected to undergo significant change over the coming decades, with natural gas combined cycle, solar, and wind growing to simultaneously meet increasing demand and displace coal and nuclear energy capacity. In the reference case, total power sector capacity is projected to increase by 71 percent through 2050, to meet a 34 percent increase in electricity demand (capacity rises at a higher rate since many resources, such as renewables and combustion turbines, operate less than half the time).

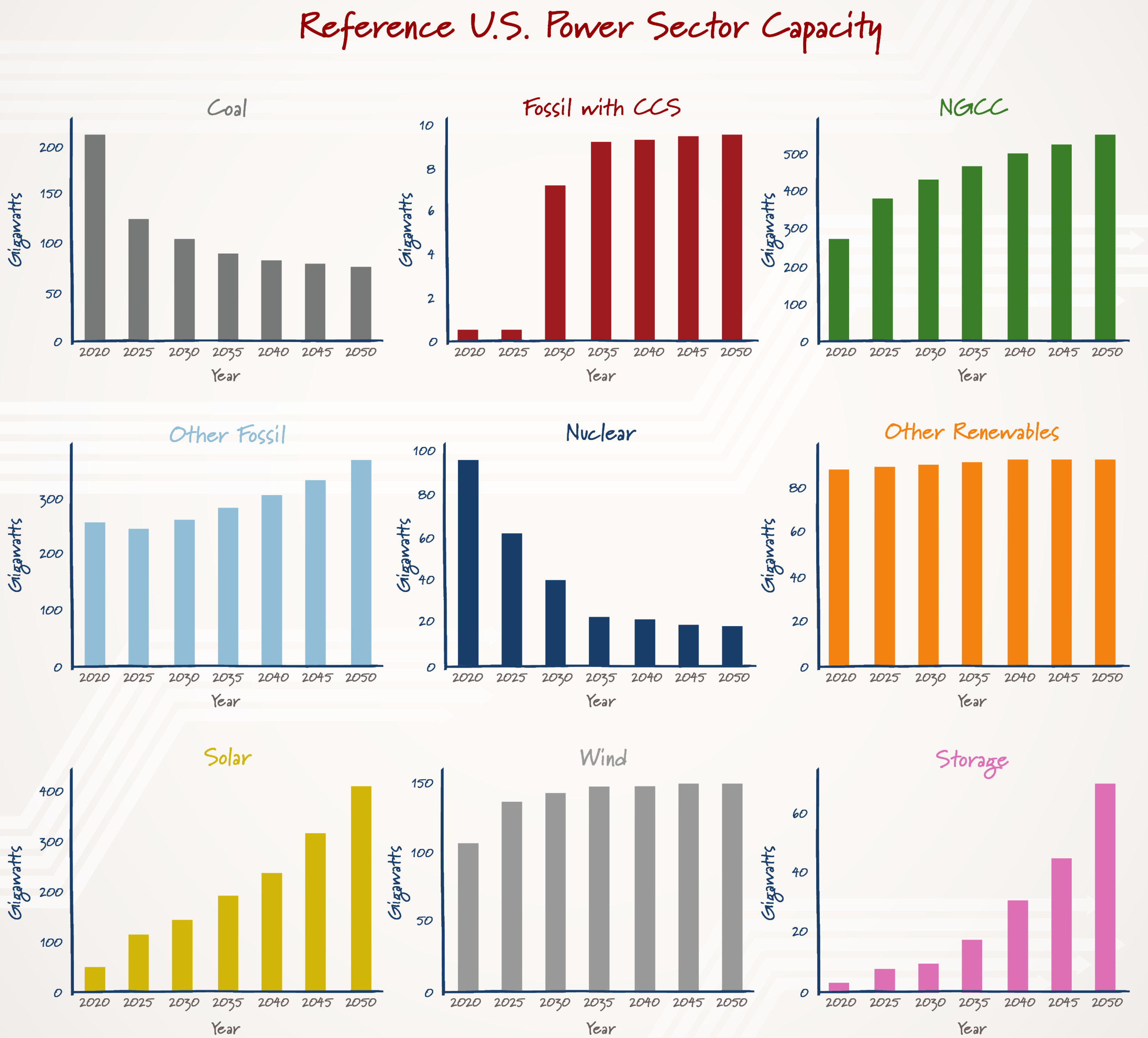
Under the reference scenario, coal and nuclear power plants are both increasingly uncompetitive compared to natural gas and renewable energy and exhibit marked declines of 63 and 81 percent, respectively. The biggest gains in capacity come from solar, natural gas combined cycle (NGCC), natural gas combustion turbines (labeled as “other fossil"), and wind. Solar and wind capacity together rise 268 percent by 2050, with most of that increase coming from solar.



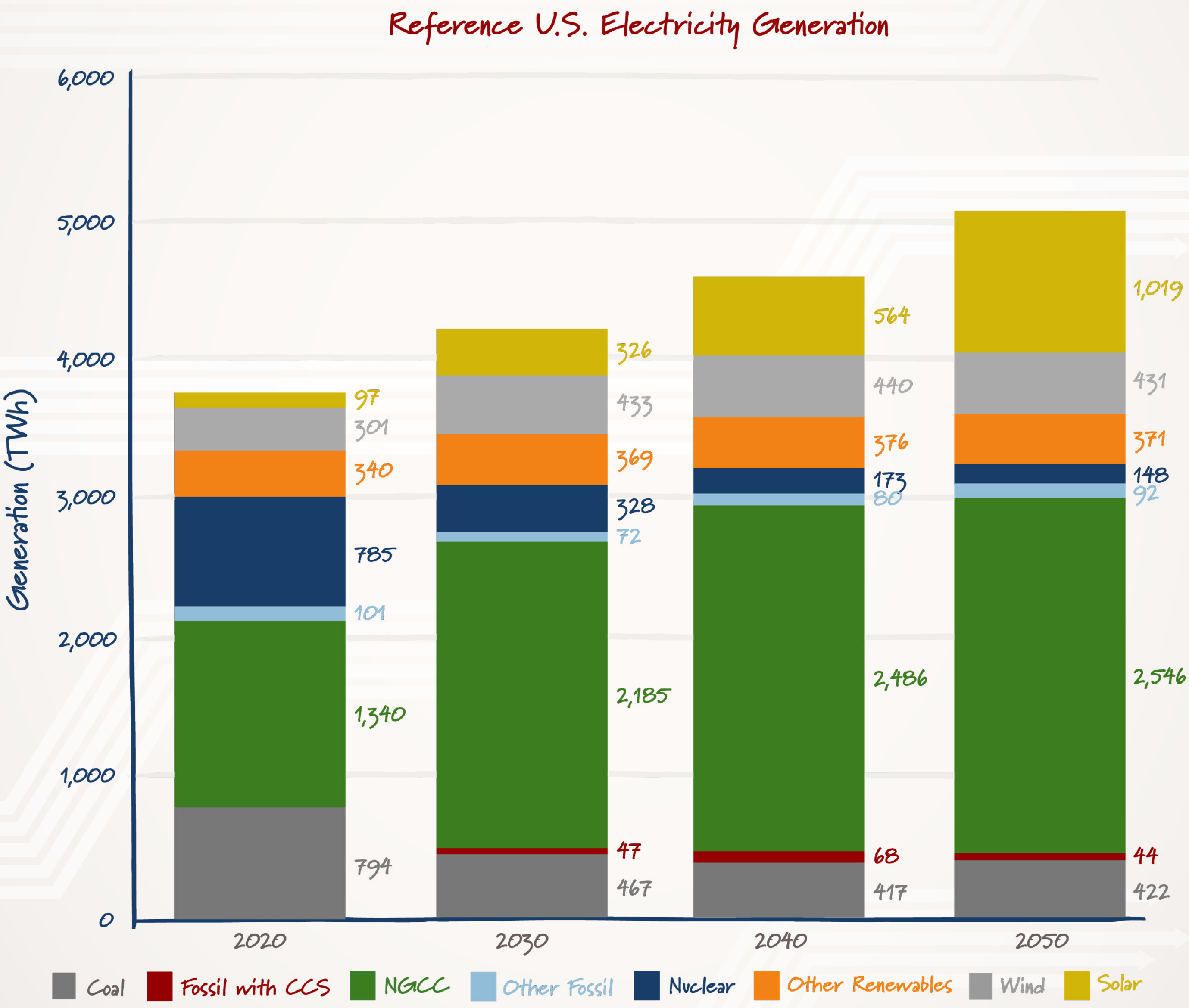
Under the reference scenario, coal and nuclear power plants are both increasingly uncompetitive compared to natural gas and renewable energy and exhibit marked declines of 63 and 81 percent, respectively. The biggest gains in capacity come from solar, natural gas combined cycle (NGCC), natural gas combustion turbines (labeled as “other fossil"), and wind. Solar and wind capacity together rise 268 percent by 2050, with most of that increase coming from solar.

Nuclear capacity particularly suffers, with a decline of nearly 80 percent between now and 2050. Because the NEMS model does not take into account the expiration of a nuclear power plant’s NRC license, all nuclear retirements not already announced are made on a purely economical basis and most of the existing nuclear capacity is considered uneconomical in the reference case.

NGCC, natural gas combustion turbines, and energy storage capacity all sharply increase as well, with combustion turbines and energy storage serving as balancing measures for increased renewables on the grid. In general, single-cycle combustion turbines are cheap to build and can ramp quickly, but they consume as much as 50 percent more fuel than natural gas combined cycle to generate the same amount of electricity. As a result, they are primarily used for balancing the grid when electricity prices are high, and on average operate for less than 10 percent of the year. Standalone battery energy storage plays a similar role in the system. Battery storage grows to 69 gigawatts of capacity in 2050, but this may be an understatement as solar and wind deployments may be paired with batteries in hybrid systems if there are improvements to economics from doing so.[36]

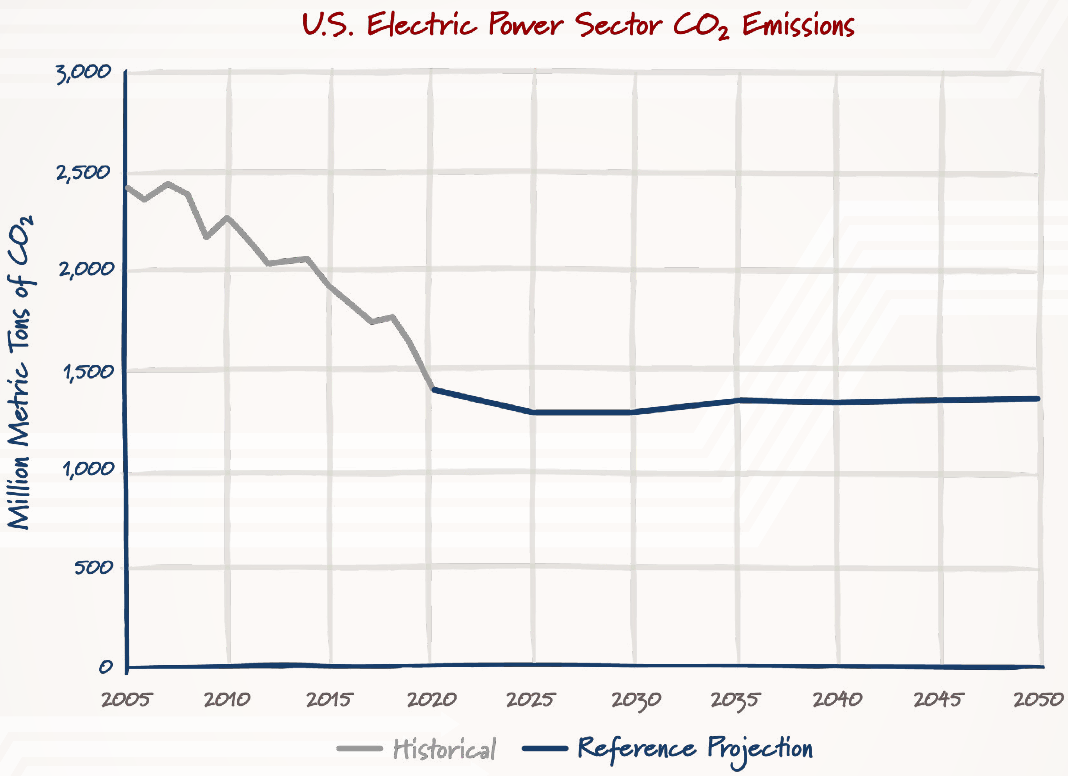


Total demand for electricity is projected to increase by 31 percent between now and 2050. Electricity from natural gas combined cycle is projected to surge through 2030, then slowly rise through 2050. Post-2030 natural gas prices increase somewhat, and renewable cost declines, which makes solar and wind much more competitive, with electricity from those two technologies ultimately more than tripling through 2050. Meanwhile coal and nuclear exhibit a significant contraction over that period. Electricity generation from "other fossil" generators (mostly gas combustion turbines) remains flat over this period despite a 40 percent increase in capacity. The average capacity factor for natural gas combustion turbines in the reference scenario is less than three percent, meaning that they are only being used for very short periods of time.



Emissions and Price Projections

One of the most interesting findings from our modeling work is the fact that power sector emissions are expected to begin slightly increasing after 2025, effectively reaching the extent of what's economically efficient with current technologies and policies. After a sharp decline over the next five years as coal plants continue to retire and are replaced with gas and renewables, carbon emissions slowly increase between 2025 and 2050, as natural gas combined cycle generation increases to displace coal and nuclear, as well as to meet increases in load. Emissions never reach current levels, ultimately leveling out at 44 percent lower than 2005.



There are several dynamics at play here, the largest of which are related to load growth, NGCC, and nuclear trends. Through 2025 the combination of switching from coal to gas and building out renewables continues to drive emissions reductions, as an average of 16 gigawatts of coal capacity comes offline each year and is backfilled by 20 GW of NGCC and 23 GW of renewables each year. Following 2025, however, economical coal-to-gas switching opportunities have been largely exhausted, and new combined cycle plants begin replacing nuclear reactors instead—with an average annual retirement of 6 GW of nuclear capacity coupled with 15 GW of NGCC additions. Aside from the replacement of nuclear capacity, much more natural gas electricity is used to meet the increased demand through 2050. The fact that emissions remain flat while electricity consumption increases by 30 percent and the economy grows is an encouraging sign, but that same load growth makes additional significant reductions more difficult.

This "cul-de-sac" of shallow decarbonization demonstrates the limits of state-level clean energy in the most climate-ambitious states. The reference scenario contains representations of all binding state-level climate and energy policies in place at the end of 2020. That means it includes the combined goals of 17 states.[37] In fact, as of 2019, the total electricity consumption in states with 100 percent clean energy requirements comprised less than 30 percent of the U.S. total, meaning that decreases in those states are easily outweighed by increased fossil generation elsewhere, such as in Florida, Georgia, Indiana, Ohio, and Texas. To date, the best that existing state-level power sector policies can do is keep emissions flat.[38] These findings demonstrate the importance of keeping existing nuclear reactors online wherever feasible. The reference scenario projects 80 percent of nuclear capacity will close by 2050. As discussed in the following section, this is unlikely to happen—but maintaining existing nuclear power makes a significant impact on future emissions reductions.

Impact of Utility Decarbonization Commitments

As discussed on page 16, 51 utilities have made significant decarbonization commitments over the last several years. Working with Rhodium Group, ClearPath developed a scenario to estimate the impact of the electric utility commitments in place as of October 2020. This scenario quantifies for the first time the potential benefit of these commitments if they are realized.

In sum, the impact of utility commitments beyond that of the reference case is significant. Many of the utility decarbonization commitments are in areas of the country without any corresponding state-level policy—meaning that in those regions utility commitments will drive clean energy progress. In total the utility commitments (UC) scenario resulted in an estimated cumulative four gigatons of additional avoided carbon emissions beyond the reference scenario, corresponding to annual emissions in 2050 of 56 percent below 2005 levels (compared to only 44 percent below 2005 levels in the reference scenario).

This change is driven by significantly lower coal and natural gas capacity, coupled with preservation of existing nuclear capacity and major increases in renewables and battery storage capacity. Compared to reference, the UC scenario projects 29 GW less coal capacity and 71 GW less NGCC capacity. Replacing that avoided fossil capacity is the preservation of 23 GW of nuclear power and an additional 187 GW of solar and wind capacity.

This modeling effort also demonstrated that at current projected costs, dispatchable clean energy technologies such as carbon capture, advanced nuclear, geothermal, and long-duration energy storage do not play a significant role in meeting the shallow levels of decarbonization achieved through existing utility commitments. The need for these technologies does exist, but it is largely needed for future energy mixes with extremely high levels of clean electricity.[39] For the purposes of this analysis, utilities with decarbonization commitments are able to purchase additional renewable energy from regions without decarbonization commitments. If each utility were required to produce all its electricity from clean sources within its service territory, it is likely that more clean dispatchable resources would be procured.

These commitments, particularly the utilities with net-zero goals, can be a big part of driving emissions reductions, so long as utilities translate those commitments into their integrated resource planning and power contracting going forward. This work also demonstrates that the combination of existing state policies and utility goals are insufficient to decarbonize the national power sector.

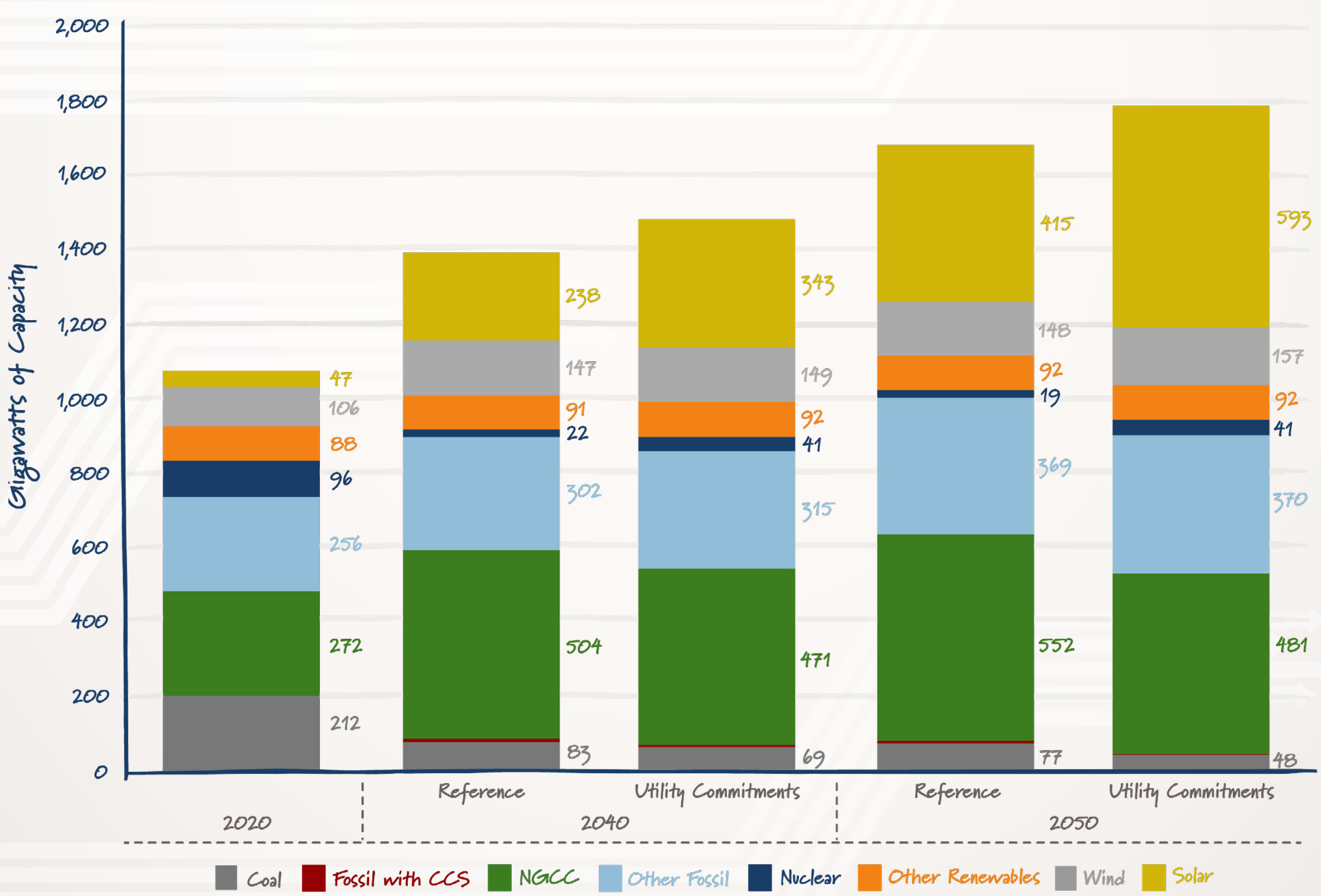
Structure of Utility Commitments Scenario

A carbon cap was placed on each utility with a decarbonization goal according to that utility's stated level of carbon reduction and a timeline as included in the Smart Electric Power Alliance's Utility Carbon Reduction Tracker.[40] To meet the carbon caps set for each utility, the model selects the lowest-cost-available resource. For traditional vertically integrated utilities, the combined emissions of all its owned assets need to be below the emissions cap, while for utilities operating in a restructured power market such as PJM, a corresponding carbon cap was placed on the percentage of sales represented by that utility in its respective region. Compliance with these carbon caps can be reached either by building new capacity or by purchasing low-emissions power in-state or regionally. These utility commitments are layered on top of existing federal and state-level clean energy and climate policies to estimate their combined effect.[41] Other underlying assumptions are identical to the reference scenario.

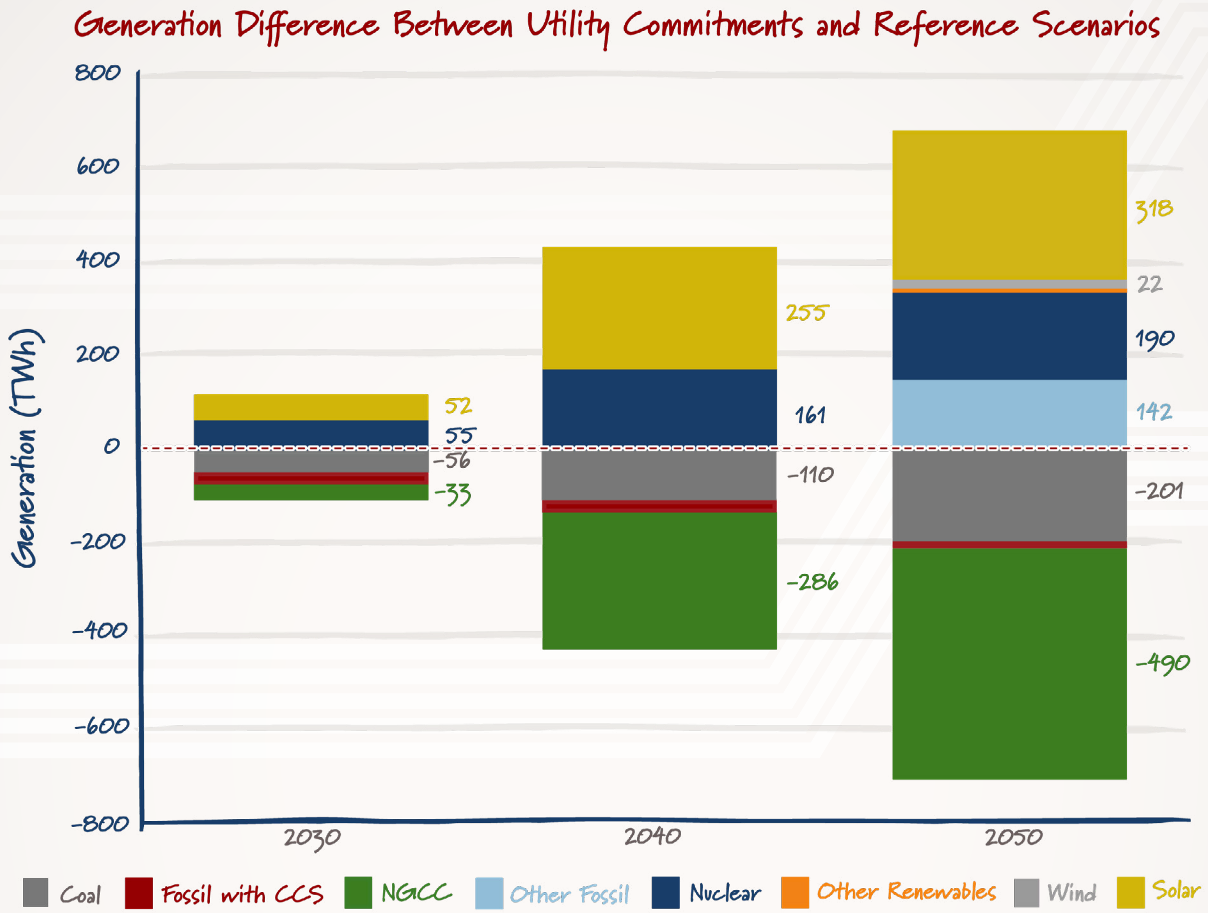
Results

Our analysis shows that if realized, the utility commitments made so far will have a significant impact on the electric sector. The UC scenario deploys 30 percent more solar and wind by 2050 than the reference scenario (most of this new renewable capacity is solar) and maintains twice as many nuclear reactors on the grid, demonstrating that a combination of new renewables and existing nuclear power is one of the cheapest carbon reduction options available. The total additional solar and wind capacity deployed by 2050 is greater than all the capacity currently installed in the U.S. Coal power capacity further declines to 48 GW, and while gas combined cycle capacity still grows significantly, it ultimately begins to plateau in 2040.

Power Sector Capacity by Scenario



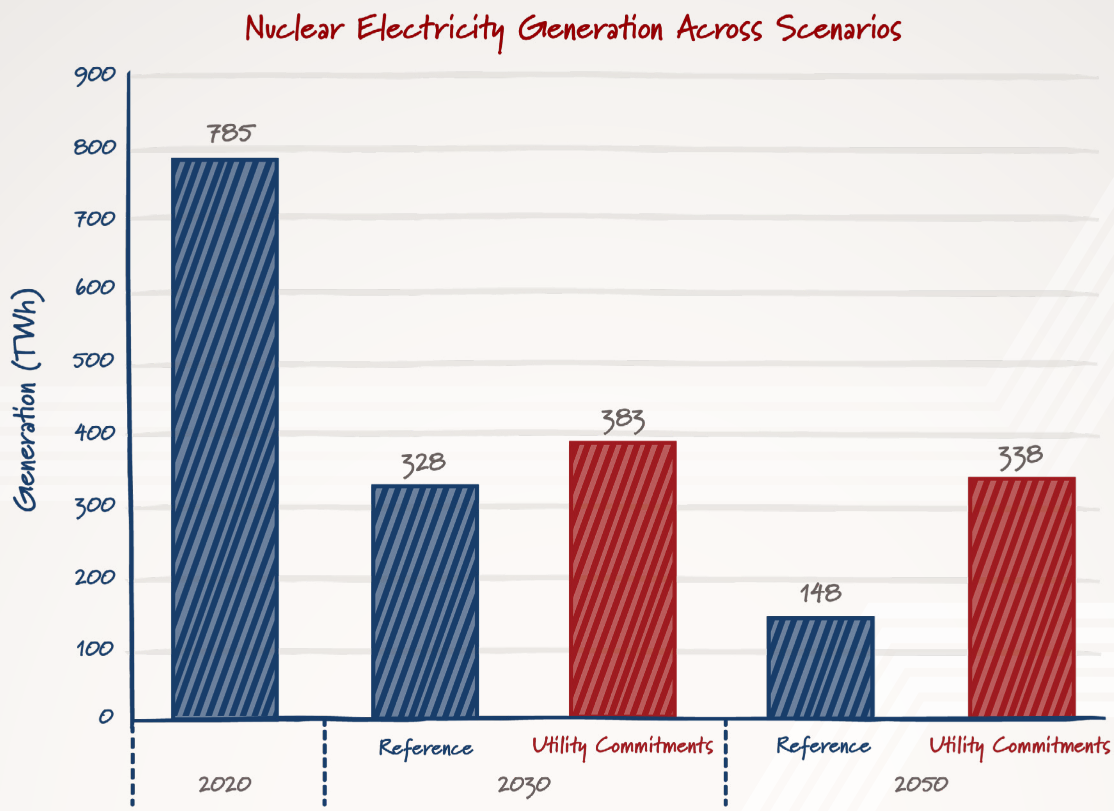
The UC scenario tells a similar story, with solar and nuclear power generation up significantly compared to the reference scenario, offsetting coal and combined cycle generation. Generation from natural gas combustion turbines more than doubles to balance increased renewable generation. By far, the biggest beneficiaries of the utility commitments made to date would be solar and nuclear energy.



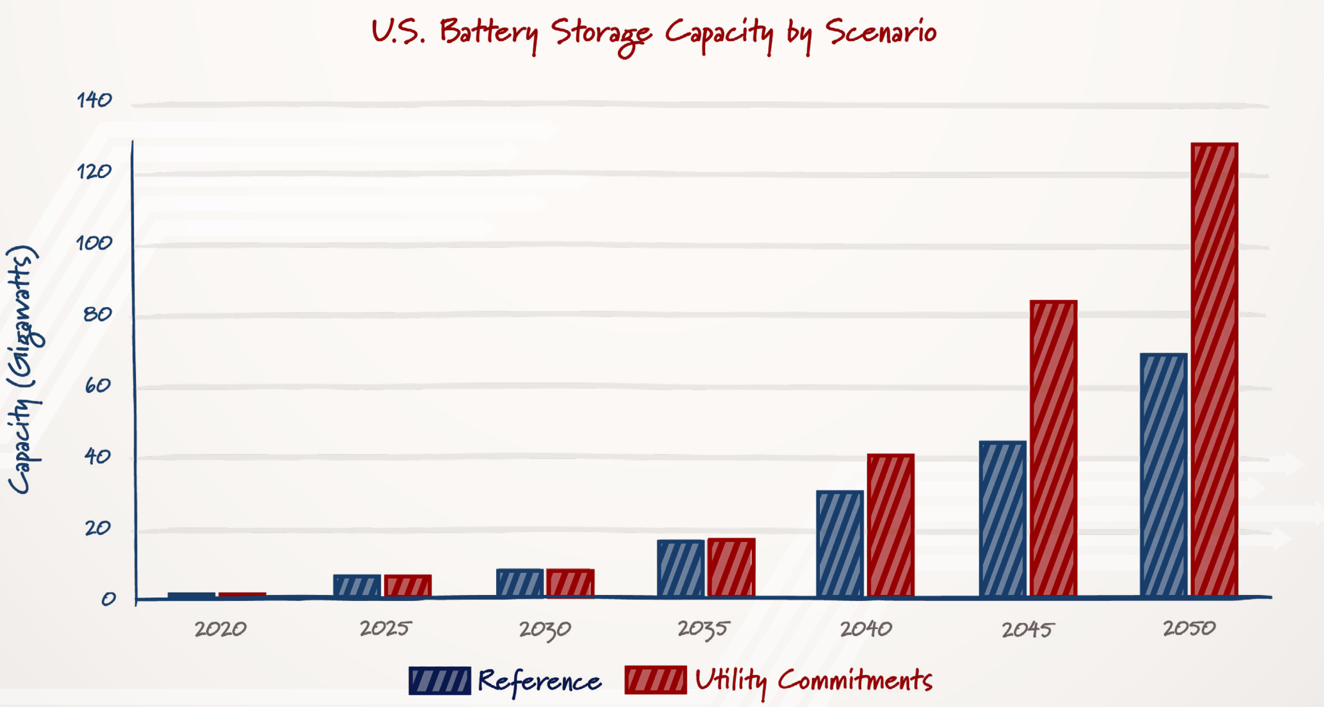
Role of Nuclear Energy

Nuclear energy is the largest source of zero-emissions electricity in the United States today, but it has faced increased economic struggles, particularly in restructured electricity markets such as PJM, NYISO, and MISO. Twelve reactors have closed in the last decade, leaving a total of 93.[42] An additional eight GW of nuclear capacity has been officially announced for retirement, but as mentioned previously, much more capacity could retire due to economic pressures in the coming years.

The UC scenario leads to 228 percent more electricity generated from nuclear reactors in 2050 than the reference. Maintaining existing nuclear power plants is one of the cheapest ways to meet clean energy goals, as demonstrated by the model, which maintained significant nuclear to keep the utilities under their carbon caps.[43] The increased generation in the UC scenario comes from 22 additional gigawatts capacity on the grid. Even more would likely be preserved if more utilities established net-zero commitments.

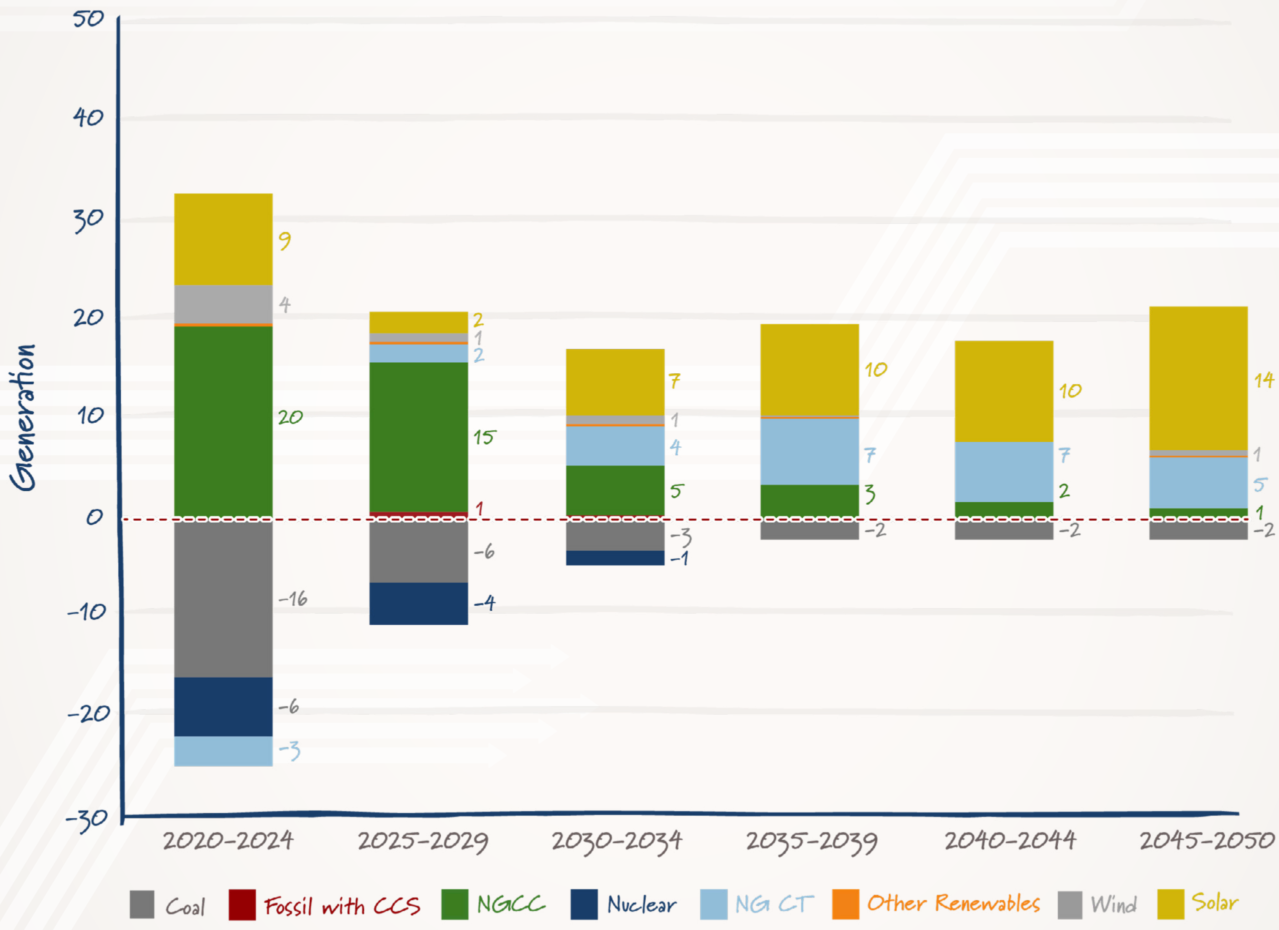


Battery storage also emerges as a clear beneficiary in the UC scenario, with nearly twice as much capacity deployed in 2050. Battery storage provides a similar balancing capability as combustion turbines, but does not contribute to the carbon cap associated with each utility's commitment.

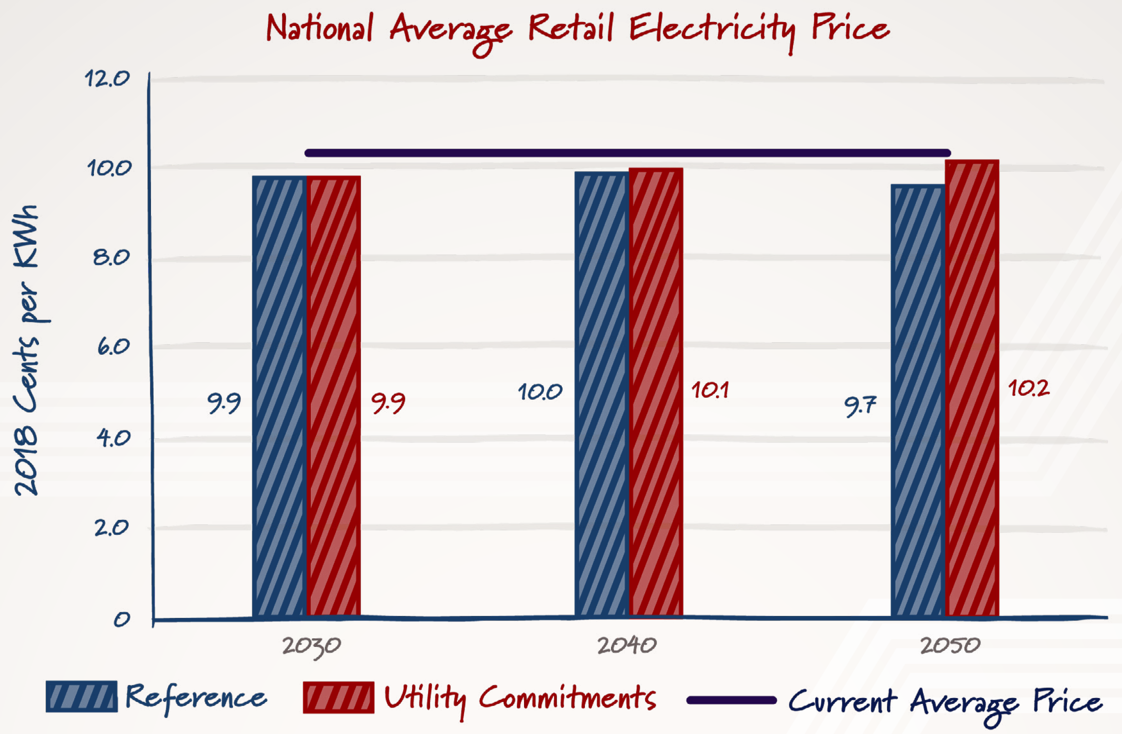


The chart below presents the average annual amount of capacity added or retired in each five year period of the UC scenario. For example, the nine GW of solar and four GW of wind added between 2020 and 2025 is an annual amount, and the total for the five-year period would be 135 GW of capacity. Solar is consistently added at a high rate throughout the study period, with more combustion turbines being added beginning in 2035 and wind additions tapering off after 2035. Most of the coal and nuclear retirement happens before 2030 and is displaced by both renewables and natural gas generation. Finally, spurred on by the 45Q carbon capture tax credit (which requires construction to commence prior to 2026) an annual average of one GW of gas with CCS is added each year between 2025 and 2030.

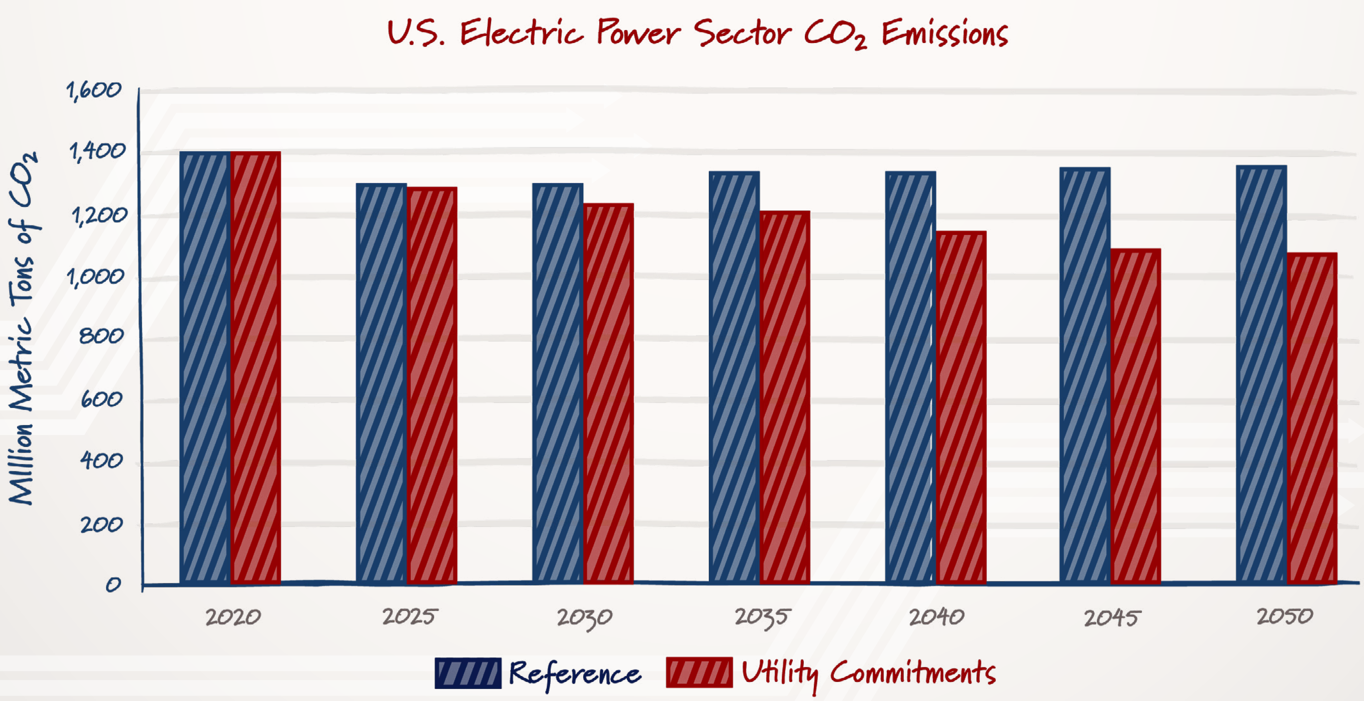
Average Annual Capacity Additions and Retirements, Utility Commitments Scenario



The analysis shows that electricity prices under the UC scenario are projected to remain at or below current prices through 2050, compared to a six percent decrease in the reference scenario. Despite 27 percent higher clean electricity generation relative to the reference scenario, the average retail price is only six percent higher, which is primarily driven by anticipated declines in the cost of electricity generation as both renewables and natural gas electricity get cheaper due to technological improvements.[44]



Carbon dioxide emissions in the power sector drop significantly below business-as-usual in the UC scenario, continuing to fall after 2025 until they hit 1,073 million metric tons in 2050. This is in contrast to the reference scenario, in which emissions are projected to increase after 2025. In total, approximately four gigatons of carbon emissions are avoided in the UC scenario compared to the reference case on a cumulative basis. Carbon emissions reduction in 2050 would represent a 56 percent decrease from 2005 levels, 21 percent lower than the reference scenario.



The Role of Dispatchable Clean Energy Is Unclear

Both the reference and UC scenarios include up-to-date cost assessments for advanced carbon capture systems (both post-combustion capture systems and Allam Cycle gas plants) and current Small Modular Reactor designs. In addition to these nascent technologies, the model includes representations of new hydro and geothermal technologies. Very little clean dispatchable power was deployed in the UC scenario, with only five gigawatts of natural gas with CCS and four new gigawatts of other renewables deployed. No SMRs were deployed.

This finding demonstrates several things. First, the current value of dispatchable clean energy is lower than the cost of that energy under an environment with fewer emissions constraints. With a limited portion of the country under a decarbonization target, it is cheaper for utilities to purchase renewable energy from other regions to meet demand than it is to build new dispatchable clean energy capacity. If a greater share of the country committed to decarbonization targets, we would expect the deployment of dispatchable clean energy technologies to increase, as the relative value of these technologies increases under a net-zero environment.

Second, cost and resource availability data for some technologies, like geothermal energy, may not be up to date. Geothermal energy is not deployed in the utility commitments scenario, which runs contrary to recent upticks in geothermal PPAs. One issue is that NEMS doesn't reflect recent breakthroughs in more advanced geothermal technology site development costs. For example, recent drilling at the Frontier Observatory for Research in Geothermal Energy (FORGE) site in Utah was completed in half the expected time through the use of modern techniques borrowed from the oil and gas sector.[45]

Third, this analysis is based purely on what resources are economically most efficient under current regulations, without other societal constraints. The ability to construct new solar capacity at the rate and scale deployed in this analysis remains unclear, due to both cancellations and queue delays,[46] supply chain and manufacturing rate limitations, and potential increases in public opposition (construction of other non-emitting resources at scale, such as advanced nuclear, could also face public opposition).[47]

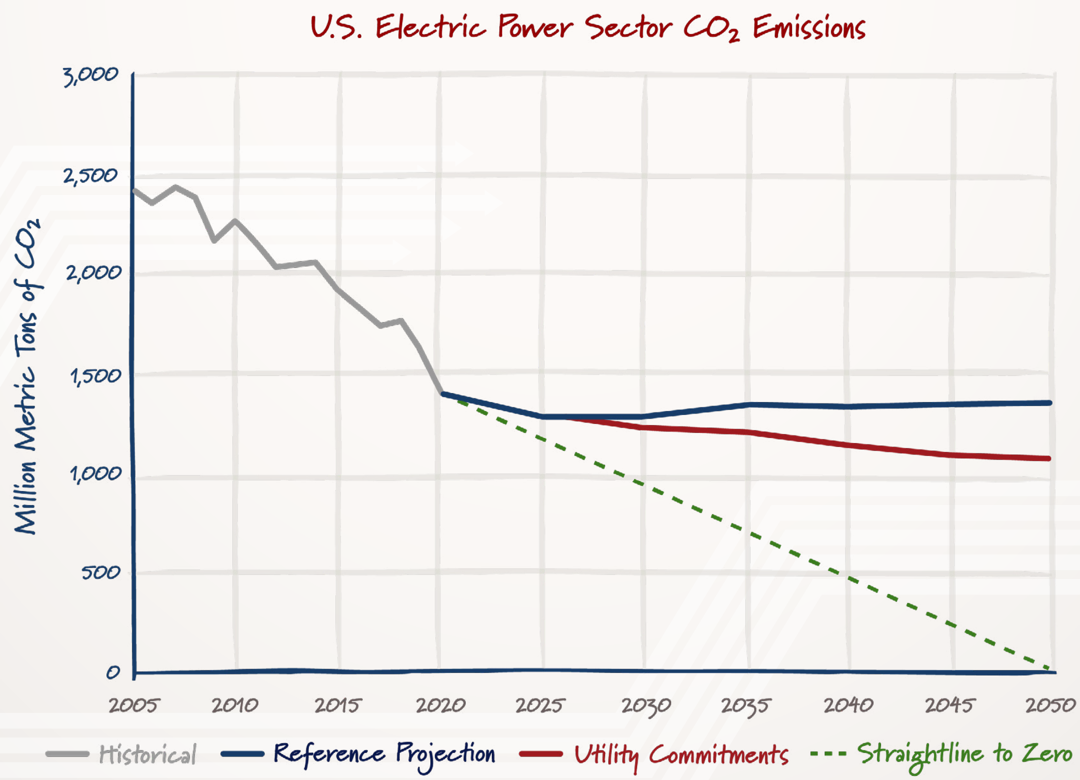
Finally, the timeline of some existing incentives are misaligned with the pace of clean energy deployment. The 45Q tax credit for carbon capture technologies provides up to $50 per metric ton of carbon dioxide sequestered, but to claim the credit, facilities must commence construction prior to 2026. As most of the significant utility decarbonization commitments enter into force between 2040 and 2050, any fossil facility going online at that time is no longer eligible for 45Q. There is a small amount of fossil with CCS development in both scenarios prior to 2030, showing that with the 45Q credit the technology can be economical. However, this small-scale deployment of less than 10 gigawatts is insufficient to lower the cost of the technology to the point that it is economical in the utility decarbonization scenario in 2040 or 2050.

Ultimately, the future role of dispatchable clean power technologies remains unclear. With significant cost declines they would have a sizable impact and lower the future cost of energy, as demonstrated by numerous recent studies.[48] As the ambition of decarbonization increases, the value of dispatchable clean energy will continue to increase.[49] To maintain these technologies as an option for deep decarbonization, R&D and early deployment support should be provided to further decrease technological and financial risks. A recent study from Resources for the Future found that cost reductions in dispatchable clean energy technologies would have large benefits, ranging from $12 billion to $32 billion depending on the policy situation.[50]

Mind the Gap: Remaining Emissions Through 2050

To limit the impacts of global climate change, greenhouse gas emissions from the global electric power sector likely need to drop below zero by 2050.[51] This is due to both the fact that the costs of clean technologies in the power sector are more readily available than other emitting economic sectors and the fact that many other decarbonization pathways outside of the power sector depend in some part on electrification of processes that currently produce emissions, e.g., internal combustion engines in transportation or fossil combustion for heat in heavy industry. This difference between the most likely future emissions scenario and net-zero is known as the emissions gap.

Closing the gap will require a steep reduction in power sector emissions. The rate of reduction required to get to net-zero by 2050 is similar to the rate of decline over the last 15 years, but the corresponding rate of clean power buildout will need to accelerate, both because most emissions will come from natural gas instead of coal and because value declines as the share of renewable energy grows in the electricity mix.



If the utility commitments made so far are taken into consideration, the gap narrows further.[52] If those commitments are realized, that gap in 2050 is 1,049 million metric tons. On a cumulative basis, compared to the net-zero trajectory, this represents an overage of approximately 15,600 million metric tons.[53]

Closing this gap will be extremely challenging. It will require increased deployment of all clean energy technologies, at a rate that has not been sustained previously, except for the rate of natural gas capacity construction in the early 2000s. That said, there are significant benefits to closing the emissions gap if it can be done affordably.

Some of the biggest challenges to closing this gap include, in no particular order:

1. The ability to site significantly enhanced or new transmission and distribution capacity to support increased renewables penetration, as many of the best renewable energy sites are not located near load centers;[54]
2. The rate of clean power project development, which is influenced by numerous issues such as financing, permitting and siting challenges, and interconnection processes;[55]
3. The combined effects of value deflation and potential cost escalation for renewables due to decreased site quality;[56]
4. The widespread availability of affordable clean dispatchable technologies such as long duration energy storage, nuclear energy, geothermal energy, and carbon capture;[57]
5. Flexible grid operation to deal with significant oversupply or undersupply of power; and
6. Incentives or regulations sufficient to spur clean power development quickly enough to reduce emissions.

These challenges can be overcome, but the difficulty of doing so should not be taken lightly. The scale of the challenge only grows if ambition to lower emissions outside of the power sector increases, as electrification of processes in the transportation and buildings sectors is seen as one of the most efficient ways to reduce emissions from those sectors.[58] In total, high levels of electrification could require total electricity generation in the United States to nearly double in just 30 years, an unprecedented rate of capacity expansion.[59]

Benefits of Closing the Emissions Gap

Rhodium Group modeled these scenarios with ClearPath's specifications using RHG-NEMS, a version of the National Energy Modeling System developed by the Energy Information Administration and maintained and modified by Rhodium Group. NEMS is a complex energy-economy modeling system for the United States.[60] NEMS projects the production, imports, exports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics.

There are significant benefits to closing this emissions gap, ranging from cleaner air to energy exports, cheaper technology, and lower climate impacts.

Cleaner Air: One of the most important benefits of closing the emissions gap is the likely resulting reduction in local air pollution. Emissions of particulate matter and its precursor molecules, including nitrogen oxides (NOx) and sulfur dioxide (SO2), lead to significant levels of increased morbidity and mortality in the United States. Annually, there are over 10,000 premature deaths due to emissions from electric generation units in the United States. While power sector emissions of criteria air pollutants have decreased significantly, in 2020 the electric power sector emitted approximately 780,000 tons of NOx and 650,000 tons of SO2.[61] Moving to cleaner energy sources, whether those are renewable sources or non-emitting fossil energy sources,[62] will lead to dramatic societal benefits. The EPA publishes estimates of the human health value of reducing PM and its precursor molecules. The EPA estimates the human health value for reducing a ton of air pollution from an electric generating station in 2030 is between $49,000 to $110,000 per ton of SO2 reduced, and between $7,200 and $16,000 per ton of NOx reduced.[63]

Using these figures, an 80 percent reduction in NOx emissions from the power sector is worth approximately $5 billion to $10 billion, while an 80 percent reduction in SO2 emissions from the power sector is worth between $25 billion and $57 billion. As the transportation sector is the largest source of NOx emissions, significant reductions in the power sector would also enable electric vehicles to operate with cleaner life-cycle emissions, further lowering air pollution.

Cheaper Technology: Greatly expanding clean energy deployment and closing the emissions gap means building a lot of clean energy capacity. Similar to the impact of prior technology buildouts, greatly scaling up technologies reduces the cost of the technologies through “learning-by-doing.” In general, many energy technologies have demonstrated that with each cumulative global doubling of their capacity, the cost of that technology will drop by a given percentage, known as the “learning rate.”[64] This effect has been particularly prominent for technologies like solar energy, which has historically decreased in cost 20 percent every time global capacity has doubled.[65] While the question of whether learning rates will hold for increasingly mature technologies remains somewhat in question,[66] the ability to drive down the cost of emerging technologies through early stage deployment is clear.

Scaling up novel clean energy and climate technologies in the United States will have local benefits,[67] but some of the greatest benefits could come internationally. Technology development programs from one country can have positive spillover effects in other countries as well.[68] By demonstrating and deploying new technology, financing, and regulatory structures in the U.S., global emissions reduction becomes much more feasible. Most future greenhouse gas emissions will be produced by other nations—reducing the cost of clean energy through a combination of dedicated research and development and learning-by-doing is one of the best ways to speed their clean energy deployment.

Climate Change Mitigation: Finally, and most importantly, reducing emissions from the power sector can mitigate the impacts of global climate change in the United States, while leveraging pressure on large emitters such as China and India to lower their own emissions. Unabated carbon emissions are expected to have significant impacts across all aspects of society, from food and water supplies to health and security. While exact impacts are uncertain, the U.S. Global Change Research Program has found a variety of impacts are already being experienced today, including but not limited to:[69]

- Significant reductions in snowpack and annual sea ice extent;
- An increase in the season length of heat waves by over 40 days in many U.S. cities since the 1960s;
- An increase in annual average temperatures of 1.8°F across the contiguous United States since the beginning of the 20th century, with Alaska's temperature increasing at twice that rate;
- A nine-inch increase in annual median sea level along the U.S. coast since the early 20th century, as oceans have warmed and land ice has melted; and
- Increased ocean acidification, potentially disrupting marine ecosystems.

Many of these climate-related changes will have a more pronounced impact in less wealthy countries, but the U.S. will also face significant effects. Reducing greenhouse gas emissions can minimize climate impacts and increase future prosperity. Furthermore, the vast majority of future greenhouse gas emissions are likely going to be emitted outside of the U.S. Reducing U.S. emissions would provide leverage to ensure that other countries reduce their emissions to acceptable levels.

Recommendations for Closing the Gap

This analysis has demonstrated a number of key actions that must be taken to close the power sector emissions gap between now and 2050.

Additional Utilities Need Net-Zero Carbon Goals. The analysis demonstrates that individual utility decarbonization goals can add up to a significant impact if they are ultimately realized. However, while much of the geographic area of the continental United States has its electricity supplied by utilities with net-zero goals, many of the larger load centers, and the areas with the fastest projected electricity growth, have limited or no decarbonization goals. Utilities are demonstrating that achieving 100 percent clean energy by 2050 is highly doable, but more companies need to follow suit. There are several large geographic areas without ambitious decarbonization goals. In addition to investor-owned utilities, federally owned utilities such as the Western Area Power Administration and the Bonneville Power Administration should follow another federal utility, the Tennessee Valley Authority, in setting decarbonization targets.

Clear Action Plans Will Lead to Clear Policy Solutions. If utilities with goals in place established regulatory filings like Integrated Resource Plans (IRPs) with clear pathways to achieve their targets, policymakers would be able to cut out the guesswork and work with them. If there are policy or technological advances needed to achieve their goal, a scenario analysis from the power companies would showcase the potential impact of various policy mechanisms or technology improvements. Many of the investments needed to achieve goals in 2040 and 2050 need to be made in the next decade, and investments on the 2030 timeline need to be made today. Some utilities have already begun this process, such as Xcel Energy.[70]

State and Federal Policy Is Still Needed for Existing Nuclear. This analysis demonstrates that extending the operation of nuclear power plants can be a cost-effective way to reduce emissions and that without action a majority of the nuclear fleet will become increasingly uneconomical over the next decade, with the reference case predicting that over half of current nuclear capacity will retire by 2030. The UC scenario shows that many reactors could be preserved due to decarbonization commitments, but to ensure this outcome, state and federal support is warranted. One potential bipartisan model is establishing federal credits for nuclear reactors on the basis of their climate benefits, a proposal developed by Senators John Barrasso (R-WY) and Shelly Moore Capito (R-WV), most recently introduced in the American Nuclear Infrastructure Act and included as part of Senate Energy and Natural Resources Chairman Manchin's infrastructure proposal.

Cheaper Dispatchable Clean Energy Is Needed. There is general agreement that dispatchable clean energy will be required to keep costs low in a 100 percent clean energy system. This study included updated cost estimates for carbon capture, small modular reactors, and geothermal and hydropower technologies, but aside from a small amount of short-term carbon capture deployment due to the 45Q tax credit, no new dispatchable clean energy was added in either the reference or utility commitment scenarios. A more diverse set of affordable clean energy resources could reduce the total amount of new capacity deployed to achieve decarbonization goals, thereby reducing the cost of achieving the targets. Programs to demonstrate cheaper dispatchable clean technologies and incentives to support early stage technologies can help reduce the cost of dispatchable technologies. A recent study from Resources for the Future, an independent, nonprofit research institution, found that cost reductions in dispatchable clean energy technologies would have large benefits, ranging from $12 billion to $32 billion annually depending on the policy situation.[71]

Near-Term Federal Policy Opportunities Can Help. There are a number of recent federal policy proposals that could help reduce the cost and timeline of decarbonizing the power sector. Some of the proposals with the greatest bipartisan support include:

a. Extending and Enhancing 45Q. Several bipartisan bills to extend and expand the 45Q tax credit have been introduced this congress. Previous research has demonstrated that extending 45Q will provide additional certainty to project developers and expanding 45Q will make the credit more appealing for the power sector. As this analysis shows, at its current level 45Q has a very limited impact in the power sector.
b. Preserving Existing Nuclear Plants. There have been several bipartisan proposals to support existing nuclear plants. One of the most popular proposals is the American Nuclear Infrastructure Act, which includes a credit program for plants that are struggling economically. Aside from ANIA, there are several tax credit-based proposals. One is the Nuclear Powers America Act, which would provide an investment tax credit for all existing nuclear plants. There were also several proposals offered as amendments at a recent markup of the Senate Finance Committee.
c. Funding "Energy Act of 2020" Demonstrations. To provide more affordable dispatchable clean energy, demonstration programs and funding for research and development can help. Another recent Resources for the Future study found that if energy innovation programs for

clean dispatchable technologies similar to those authorized in the Energy Act of 2020 are appropriated at the levels authorized, each technology would generate projected societal benefits averaging $30 billion to $40 billion in present value per technology between 2040 and 2060. Funding for the demonstration projects authorized in the Energy Act of 2020 was proposed in the recent bipartisan infrastructure deal, which would be a large down payment on many of the elevated R&D levels authorized by the Energy Act.

d. Supporting the Energy Sector Innovation Credit (ESIC). Tax incentives are another method to support initial deployment of innovative clean energy technologies. One option is the Energy Sector Innovation Credit (ESIC), a tax credit proposed by Senators Mike Crapo (R-ID) and Sheldon Whitehouse (D-RI) and U.S. Representatives Reed (R-NY), Lahood (R-IL) and Panetta (D-CA) that would support any new power sector technology with an investment tax credit or production tax credit, until that technology reaches three percent of total electricity generation. This levels the playing field for non-incumbent technologies, drawing them into the market by driving down costs.

e. Improving Energy Infrastructure Permitting. The rate of energy infrastructure development could be a major impediment to closing the infrastructure gap by 2050. There is a growing understanding that to build enough clean energy on the correct timescale, federal, state, and local permitting will need to improve drastically. Public policy solutions that both protect the environment and accelerate approvals for some clean energy projects could be one way to build at the scale required. Expanding transmission capacity, particularly interstate high-voltage transmission capacity, is an extremely difficult and uncertain process, but it could also be one of the best ways to affordably reduce emissions on a large scale.

Conclusion

It is increasingly clear that the United States is hitting the edge of shallow decarbonization opportunities following initial renewable energy development and a large-scale switch from coal to gas since 2005. Natural gas, solar, and wind are the name of the game, and they are the only new technologies expected to develop for the foreseeable future, unless natural gas prices keep going up or dispatchable clean technologies decrease in cost. While renewables are on the rise, potential zero-carbon nuclear reactor retirements and increasing load growth in states without clean energy mandates mean that power sector emissions are projected to stay flat through 2050 unless there are new innovations.

Utility commitments are emerging as a potential bright spot, adding meaningful carbon reductions beyond the flatline anticipated under current trends. Realizing those reductions will require new technology and policy support but can ultimately be accomplished while keeping electricity prices flat. Even with the existing utility commitments, the U.S. is not on track to close the remaining emissions gap with existing technology—projected 2050 carbon emissions are only 56 percent lower than 2005 levels. Unless the U.S. has a clearer path for carbon capture technology for natural gas and an accelerated path for developing new projects, decarbonization rates will only get more difficult. Several clear near-term steps must be taken to maintain momentum toward a clean energy future. Some of the most salient game-changers include (1) more utilities establishing decarbonization targets and clearly delineating their plans to achieve those targets, (2) enacting policy mechanisms to preserve existing nuclear, and (3) making major investments in new technologies to aid deep decarbonization.

The private sector increasingly believes that it is both practical and profitable to decarbonize the power sector. Itt remains to be seen whether utilities will have the tools to follow through on their decarbonization targets in a timely manner, and whether federal and state policy will support their targets. ClearPath to a Clean Energy Future will continue as a series, publishing the latest clean energy trends, tracking utility decarbonization commitments, and providing federal policy recommendations to support accelerating technology deployment.

Appendix A: States with 100 percent Clean Energy Targets

State	Final Target Year	Target Type	Year Established
Arizona	2070	Regulatory Order	2020
California	2045	Legislative Requirement	2018
District of Columbia	2032	Legislative Requirement	2018
Hawaii	2045	Legislative Requirement	2018
New Mexico	2045 (IOUs and munis); 2050 (co-ops)	Legislative Requirement	2019
New York	2040	Legislative Requirement	2019
Puerto Rico	2050	Legislative Requirement	2019
Virginia	2050	Legislative Requirement	2020
Washington	2045	Legislative Requirement	2019
Colorado	2050	Legislative Requirement (Xcel Only)	2019
Oregon	2040	Legislative Requirement	2021
Maine	2050	Executive Order/Non Binding Goal	2019
New Jersey	2050	Executive Order/Non Binding Goal	2018
Rhode Island	2030	Executive Order/Non Binding Goal	2020
Wisconsin	2050	Executive Order/Non Binding Goal	2019
Connecticut	2040	Executive Order/Non Binding Goal	2019
Maryland	2040	Executive Order/Non Binding Goal	2019
Nevada	2050	Executive Order/Non Binding Goal	2019
North Carolina	2050	Executive Order/Non Binding Goal	2019

Appendix B: State Economy-wide Emissions Reduction Requirements

State	Emission Reduction Target (%)	Target Year	Year Enacted
Colorado	90	2050	2019
Connecticut	80	2050	2009
Hawaii	100	2045	2007; 2018
Maine	100	2045	2019
Maryland	40	2030	2009; 2016
Massachusetts	100	2050	2021
Minnesota	80	2050	2007
New Jersey	80	2050	2006
New York	100	2050	2019
Puerto Rico	50	2024	2019
Rhode Island	100	2050	2021
Vermont	80-90	2050	2005; 2016

Appendix C: Significant Utility Decarbonization Commitments

Utility	State	Final Target Year	Emission Reduction Goal
Minnesota Power	MN	2050	100% carbon-free energy by 2050.
Public Service Company of New Mexico	NM	2040	70% emissions-free energy by 2032, and 100% emissions-free energy by 2040.
Platte River Power Authority	CO	2030	100% non-carbon energy mix by 2030.
Portland General Electric	OR	2040	80% reduction in GHG emissions from 2010 levels by 2030. Net-zero GHG emissions by 2040.
East Kentucky Power Cooperative, Inc	KY	2050	70% reduction in CO2 emissions from 2010 levels by 2050.
PPL Corp	PA	2050	80% reduction in CO2 emissions from 2010 levels by 2050.
UGI Utilities, Inc	PA	2025	55% reduction in Scope 1 GHG emissions from 2020 levels by 2025
North Carolina Electric Membership Corporation	NC	2050	50% reduction in CO2 emissions from 2005 levels by 2030 and net-zero carbon emissions by 2050.
Northern Indiana Public Service Company	IN	2028	90% reduction in CO2 emissions from 2005 levels by 2028. All coal plants closed by 2028.
Tucson Electric Power	AZ	2035	80% reduction in CO2 emissions from 2005 levels by 2035.
La Plata Electric Association, Inc.	CO	2030	50% reduction in carbon footprint from 2018 levels by 2030.
Arizona Public Service	AZ	2050	100% carbon-free power by 2050. 65% clean energy by 2030.
Madison Gas & Electric Company	WI	2050	Net-zero carbon electricity by 2050.
Otter Tail Power Company	MN	2022	40% reduction in carbon emissions from 2005 levels by 2022.
Omaha Public Power District	NE	2050	Net-zero carbon emissions by 2050.

Utility	State	Final Target Year	Emission Reduction Goal
PacifiCorp	OR	2030	60% reduction in GHG emissions from 2005 levels by 2030.
Old Dominion Electric Cooperative	VA	2050	50% reduction in carbon intensity from 2005 levels by 2030. Net-zero carbon dioxide emissions by 2050.
Oklahoma Gas & Electric	OK	2030	50% reduction in CO2 emissions from 2005 levels by 2030.
Ameren Corporation	MO	2050	50% reduction in carbon emissions from 2005 levels by 2030, 85% reduction in carbon emissions from 2005 levels by 2040 and net-zero carbon emissions by 2050.
Vectren Corporation	IN	2023	60% reduction in carbon emissions by 2023 by retiring three coal plants and terminating ownership of another.
NextEra Energy, Inc.	FL	2025	67% reduction in CO2 emissions rate from 2005 levels by 2025.
WEC Energy Group	WI	2050	60% reduction in carbon emissions from electric generation from 2005 levels by 2025; 80% reduction in carbon emissions from electric generation from 2005 levels by 2030. Net-zero carbon emissions from electric generation by 2050.
Puget Sound Energy	WA	2045	Beyond net-zero by 2045, which includes: a carbon-neutral electric system by 2030 and 100% clean electricity by 2045.
Public Service Electric & Gas	NJ	2030	Net-zero GHG emissions for scope 1 and 2 emissions by 2030. 100% GHG-free power generation by 2030.
National Grid (US)	MA	2050	45% reduction in GHG emissions by 2020, and net-zero carbon emissions by 2050.
Tampa Electric Company	FL	2050	55% reduction in carbon emissions from 2005 levels by 2025. 80% reduction in carbon emissions from 2005 levels by 2040. Net-zero carbon emissions by 2050.

Utility	State	Final Target Year	Emission Reduction Goal
Alliant Energy	WI	2050	50% reduction in carbon dioxide emissions by 2030. Net-zero carbon dioxide emissions by 2050. Sacramento Municipal Utility District
Sacramento Municipal Utility District	CA	2030	Carbon-neutral by 2030
Idaho Power Co.	ID	2045	Average CO2 emissions intensity of energy sources from 2010 to 2020 is 15% to 20% lower than 2005 levels. 100% clean energy by 2045.
Entergy Corporation	LA	2050	50% reduction in CO2 intensity from 2000 levels by 2030. Target specific to Entergy New Orleans: 70% clean power by 2030. Net-zero carbon emissions by 2050.
Green Mountain Power	VT	2025	100% carbon-free energy by 2025
Xcel Energy	CO	2050	85% reduction in carbon dioxide emissions from 2005 levels by 2030, and 100% carbon-free electricity by 2050.
Consolidated Edison Company of New York, Inc.	NY	2040	100% clean energy by 2040.
Tennessee Valley Authority	TN	2050	70% reduction in carbon emissions from 2005 levels by 2030; 80% reduction in carbon emissions from 2005 levels by 2035. Net-zero carbon emissions by 2050.
Dominion Virginia Power	VA	2050	Net-zero emissions by 2050. 65% reduction in methane emissions by 2030 and 80% by 2040, by 2010 levels.
Duke Energy	NC	2050	At least a 50% reduction in CO2 emissions from 2005 levels by 2030. Net-zero CO2 emissions by 2050.
Hawaiian Electric	HI	2045	Carbon-neutral by 2045.
El Paso Electric	TX	2035	25% reduction in carbon footprint from 2015 levels by 2025, and a 40% reduction in carbon footprint from 2015 levels by 2035.

Utility	State	Final Target Year	Emission Reduction Goal
Evergy, Inc.	KS	2045	70% reduction in carbon emissions from 2005 levels by 2030. Net-zero carbon emissions by 2045.
Pacific Gas & Electric	CA	2045	100% zero-carbon electricity by 2045.
FirstEnergy Corp.	OH	2050	30% reduction in greenhouse gas (GHG) emissions from 2019 levels by 2030. Carbon neutral by 2050.
Tri-State Generation and Transmission Association	AR	2030	50% clean energy by 2024. 70% clean energy by 2030. 90% reduction in CO2 emissions across generation owned or operated in Colorado by 2030. 80% reduction in CO2 emissions associated with wholesale electricity sales in Colorado by 2030.
Great River Energy	MN	2023	95% CO2 free by 2023.
DTE Energy	NY	2050	32% reduction in carbon emissions by 2023, 50% reduction in carbon emissions by 2030, 80% reduction in carbon emissions by 2040. Net-zero carbon emissions by 2050.
Southern Company	AL	2050	Net-zero carbon emissions by 2050 with an intermediate goal of a 50% reduction of GHG emissions from 2007 levels by 2030.
Consumers Energy	MI	2040	Net-zero carbon emissions by 2040.
AVANGRID	NY	2035	Reduce the intensity of Scope 1 greenhouse gas emissions of our generation capacity by 35% from 2015 levels by 2025. Scope 1 carbon neutral by the year 2035.
Cobb EMC	GA	2030	75% reduction in carbon emissions by 2030.
Vermont Electric Cooperative	VT	2023	100% carbon-free power supply by 2023.
Poudre Valley Rural Electric Association, Inc.	CO	2030	80% carbon-free energy by 2030.
Holy Cross Energy	CO	2030	100% carbon-free electricity by 2030.
Avista Utilities	WA	2045	Carbon neutral electricity supply by the end of 2027. 100% clean energy by 2045.

Utility	State	Final Target Year	Emission Reduction Goal
American Electric Power	OH	2050	80% reduction in carbon dioxide emissions from 2000 levels by 2030. Net-zero carbon dioxide emissions by 2050.
AES Corporation	VA	2040	Net-zero carbon emissions from electricity sales by 2040. Net-zero carbon emissions for all business scopes by 2050.
Southern Minnesota Municipal Power Agency	MN	2030	90% reduction in CO2 emissions from 2005 levels and 80% carbon-free energy by 2030.
Southern California Edison	CA	2045	100% carbon-free power by 2045.
NorthWestern Energy LLC	SD	2045	90% reduction of carbon intensity by 2045 from 2010 levels for its Montana service territory.
Long Island Power Authority	TX	2040	100% carbon-free electric grid by 2040.
San Diego Gas & Electric	CA	2045	100% zero-carbon energy by 2045.
Black Hills Corporation	SD	2040	40% reduction in GHG emissions intensity from 2005 levels by 2030 and a 70% reduction in GHG emissions intensity from 2005 levels by 2040.

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