ENERGY INNOVATION
POLICY & TECHNOLOGY LLC

www.energyinnovation.org
98 Battery Street; San Francisco, CA 94111
policy@energyinnovation.org

A NATIONAL CLEAN ELECTRICITY STANDARD TO BENEFIT ALL AMERICANS

MIKE O'BOYLE, SARA BALDWIN, SARAH SPENGEMAN, ENERGY INNOVATION
TAYLOR MCNAIR, GRIDLAB
AMOL PHADKE, NIKIT ABHYANKAR, UMED PALIWAL, UNIVERSITY OF CALIFORNIA, BERKELEY

APRIL 2021

INTRODUCTION

America needs an economic recovery strategy that can simultaneously support critical infrastructure upgrades, expedite the transition to clean energy, ensure climate stability, and provide pathways to prosperity for all Americans. COVID-19 has exacerbated long-standing inequities that must be addressed as part of any recovery plan. President Joe Biden's American Jobs Plan (AJP) includes several policy proposals to support these ambitious goals, including an Energy Efficiency and Clean Electricity Standard (CES) that ensures "robust and rigorous standards for worker, public, and environmental safety as well as environmental justice—and all while moving toward 100 percent carbon-pollution free power by 2035."[1]

Several analyses find that a clean electricity system is the linchpin of a low-carbon, low-cost energy system. Dramatically reducing greenhouse gas emissions and other harmful pollutants in the electricity sector unlocks economy-wide decarbonization and generates major public health improvements. Due to recent and projected cost declines for renewable energy and batteries, an affordable, reliable, low-carbon electricity system is within reach this decade. Just as importantly, a rapid transition to a modern, clean electricity system creates hundreds of thousands of well-paying jobs.

The Biden administration goal of 100 percent clean power by 2035 implies an interim goal of at least 80 percent by 2030. Proven and promising technologies can get us there, though the exact combination of clean resources will be influenced by market forces. **A strong federal CES is needed to support consistent investment in these low-cost zero-carbon resources and technologies.**

Indeed, there is widespread and growing consensus among energy experts and practitioners that achieving 80 percent clean electricity by 2030 is technologically feasible without compromising reliability and affordability. For example, 13 electric utilities issued a letter to President Biden calling for a CES to reduce emissions from the electricity sector 80 percent by 2030.[2] AEP, a

utility with deep roots in Appalachian coal country and the industrial Midwest, announced on its most recent earnings call that it intends to invest in 16,600 megawatts (MW) of renewable energy projects by 2030 and retire 8,000 MW of fossil, meeting a goal of 80% emissions reductions by 2030.[3] Its CEO forecast this would benefit communities that depend on AEP for employment and low-cost energy: "By focusing on investments in support of clean, affordable and reliable energy, our customers and communities will be well positioned to adapt to the needs of our clean energy economy."[4]

Recognizing this opportunity, members of Congress have introduced in the past two years at least five legislative proposals that would set national standards for decarbonizing the power sector.[i] These proposals largely align in three ways: 1) which power generation technologies would qualify as "clean energy" to meet the standard; 2) the penalties imposed on electric utilities for falling short of the standard; and 3) provisions for flexibility on how and when obligations are met. Three bills propose standards for electric utilities to reduce carbon, while two require utilities to procure increasing shares of clean electricity. However, the House CLEAN Future Act (H.R. 1512)[5] is the only bill that aligns with President Biden's power sector commitment to achieve 80 percent clean power by 2030 and 100 percent clean power by 2035, though partial crediting of gas in this measure may undermine the affordability of these goals.

Recent studies have modeled various aspects of a net-zero carbon future, including the impacts of achieving high penetrations of clean electricity. As a further contribution to this growing body of research, a team from University of California, Berkeley, GridLab, and Energy Innovation modeled the impacts of an 80 percent by 2030 CES, the findings of which are documented in *The 2030 Report: Powering America's Clean Economy* (hereinafter The 2030 Report). The study replicated the methodology used in the team's earlier *2035 Report: Plummeting Solar, Wind, and Battery Costs Can Accelerate Our Clean Electricity Future* (June 2020), which examined the feasibility, economics, societal benefits, and labor impacts of achieving 90 percent clean electricity by 2035. The 2030 Report similarly finds that achieving an 80 percent clean electricity system by 2030 is feasible and would not increase costs to consumers.[6] Furthermore, the modeling finds widespread benefits to enacting such a policy.

---

[i] The Clean Energy Standard Act of 2019 (S. 1359) requires electric utilities to achieve 90 percent clean energy by 2040 and 100 percent clean energy by 2050. The Clean Energy Innovation and Deployment Act of 2020 (H.R. 7516) requires electric utilities to achieve a 50 percent reduction in carbon emissions by 2030 (relative to 2005 levels) and net-zero emissions by 2050; it also includes provisions allowing for an earlier net-zero target should certain requirements around technology cost reductions be met. The Tradeable Performance Standards Act of 2020 (H.R. 8582) would require electric utilities to achieve a 40 percent reduction in carbon emissions by 2030 (relative to 2019 levels) and a 100 percent reduction by 2040. The Clean Energy Future Through Innovation Act of 2020 (H.R. 9054) would require electric utilities to achieve an 80 percent reduction in carbon emissions by 2050 (relative to the year of the bill's enactment), with substantial funding for carbon capture and storage. The CLEAN Future Act of 2021 (H.R. 1512) would require electric utilities to achieve 80 percent clean energy by 2030 and 100 percent clean energy by 2035. It also fosters the expansion of the nation's grid, such as by directing federal agencies to plan for and mitigate siting challenges associated with building new transmission lines.

The 2030 Report corroborates and strengthens the findings of numerous other studies, including recent analysis conducted by Vibrant Clean Energy,[7] Princeton University,[8] Lawrence Berkeley National Laboratory,[9] and Energy Innovation.[10] Together, this body of work demonstrates that adopting a federal CES of 80 percent by 2030 would yield widespread benefits to the U.S. economy, consumers, the environment, and public health.

The purpose of this report is to highlight the consensus among these studies' findings and articulate seven reasons why the U.S. should adopt an 80 percent CES by 2030:

1. Investment and Jobs: An 80 percent by 2030 CES coupled with high labor standards will drive significant investments that will create opportunity in every region of the country.
2. Public Health: An 80 percent by 2030 CES dramatically reduces air pollution, improves public health, and advances environmental justice.
3. Climate Stability: An 80 percent by 2030 CES will help ensure a safe climate future, putting the U.S. on the path to achieve a carbon-free electricity system in 2035, and net-zero emissions by 2050.
4. Reliability: The U.S. electricity system can continue to operate reliably with 80 percent clean electricity in 2030, while also supporting electrification of transportation, buildings, and industry.
5. Affordability: An 80 percent by 2030 CES will not increase consumer costs and may even lower consumer electricity bills.
6. Feasibility: An 80 percent by 2030 CES is feasible even with economy-wide electrification, requiring rapid but not unprecedented infrastructure build-out.
7. Innovation: Working toward an 80 percent by 2030 CES will spur innovation on the path to 100 percent, and federal research and development investments can jumpstart deployment of emerging clean energy technologies.

INVESTMENT AND JOBS

AN 80 PERCENT BY 2030 CES COUPLED WITH HIGH LABOR STANDARDS WILL DRIVE SIGNIFICANT INVESTMENTS THAT WILL CREATE OPPORTUNITY IN EVERY REGION OF THE COUNTRY

Clean electricity and energy efficiency have been remarkable job creators for U.S. workers. In 2019, the renewable energy and energy storage industries employed about 600,000 workers, mostly in solar energy.[11] In fact, in that same year, renewable generation employed nearly 2.5 times more workers than fossil fuel electric power generation.[12] In 2020, the energy efficiency sector employed 2.38 million Americans, adding 300,000 new jobs in just four years.[13] As shown in Figure 1, from 2015 to 2019, the clean energy industry grew 70 percent faster than total U.S. employment.[14]

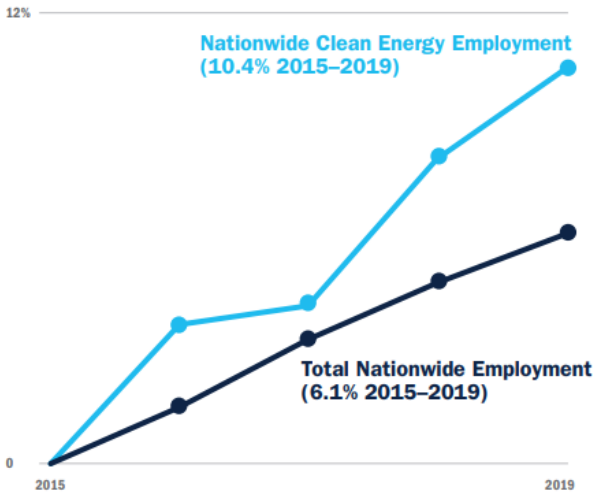

Figure 1. Nationwide clean energy employment compared with total nationwide employment, 2015 - 2019. Source: Clean Jobs America 2020: Repowering America's Economy in the Wake of COVID-19, E2, April 2020, 11.

Meanwhile, coal employment—including power generation and mining—declined throughout the 2010s, exacerbated by the COVID-19 pandemic. Since 2012, the coal mining industry lost more than half of its workforce, falling to just over 40,000 jobs in 2020.[15] Coal power generation lost 8 percent jobs in 2019,[16] with even greater losses expected in 2020.[17] The adverse impacts that coal communities have endured as a result of these changes underlines the need to ensure they benefit from the transition to a clean energy economy, as recently outlined by the United Mine Workers of America Energy Transitions Initiative.[18]

An 80 percent by 2030 CES is integral to a broader recovery strategy to repair the economic damage wrought by the pandemic. It would create hundreds of thousands of new jobs in wind, solar, and storage—helping to offset net employment losses in fossil generation. The 2035 Report, which results in 70 percent clean electricity in 2030 on the path to 90 percent clean electricity by 2035, showed that a CES supports an average increase of 500,000 jobs through 2035. It stands to reason that with increased energy efficiency and electrification of transportation, buildings, and industry, as well as a higher CES of 80 percent by 2030, job gains would be even greater. These numbers are corroborated by the Princeton Net Zero America study, which finds a net increase of 500,000 to 1 million jobs in the 2020s, spurred by the transition to a 70 percent to 85 percent clean electricity system.[19]

As shown in Figure 2, an 80 percent by 2030 CES would likely be a boon for rural and politically conservative states, including states traditionally dominated by coal and gas generation. The

2030 Report analysis finds an 80 percent CES would drive $1.5 trillion in clean energy capital investments and $100 billion in transmission capital investments spread across the country from 2021 to 2030.[20] These investments come with jobs, but just as important, they can support broader revitalization in rural communities through increased tax revenues and induced economic activity.

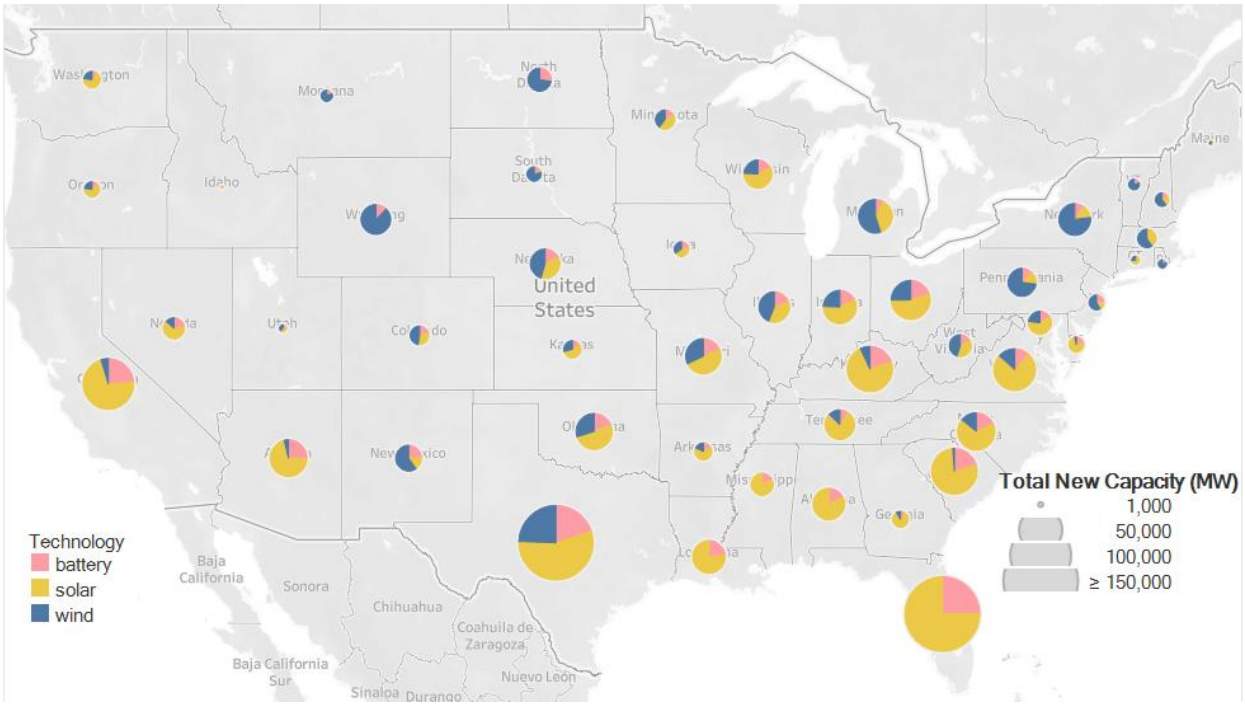

Figure 2. Map showing the estimates of new capacity investments in wind, solar, and battery technologies under an 80 percent by 2030 CES. Source: 2030 Report.

President Biden's AJP pledges to pair support for clean electricity with "strong labor standards to ensure the jobs created are good-quality jobs with a free and fair choice to join a union and bargain collectively." Among other provisions, the AJP includes plugging abandoned mines and wells and supporting domestic manufacturing of clean energy technologies to create these good-quality jobs. These plans align well with the United Mine Workers of America's (UMWA) recent support for a clean energy transition that creates jobs in coal country at prevailing union wages.[21] Specifically, the UMWA's plan calls for federal investments in carbon capture and sequestration, support for clean energy manufacturing in coal communities, funding for local coal remediation projects, and direct support for families displaced by coal's decline.[22]

Though wind and solar jobs are often cited as inferior wage providers to fossil jobs, federal prevailing wage requirements for clean electricity projects could support higher wages with negligible effects on the cost of electricity. A working paper from two authors of the Princeton Net Zero Study finds that increasing wind and solar average wages by 20 percent would earn workers $73,000 and $77,000, respectively—well over the average earnings for fossil generation jobs in the power sector.[23] Because labor is a relatively small component of capital-intensive

wind and solar projects, a 20 percent wage increase would only increase the total cost of solar power by 3 percent, and wind by 4 percent.

Additionally, producing more solar domestically rather than relying on imports would only negligibly increase capital costs, while creating jobs. The working paper finds that increasing domestic solar manufacturing from 11 percent of the total produced today to 100 percent of U.S. installed solar would increase costs of utility scale solar by just 7 percent. Because more than 70 percent of wind turbines are already manufactured domestically, increasing this share to 100 percent would have a nominal impact on cost.[24] For this reason, public investment in solar domestic manufacturing capacity is a low-cost strategy to dramatically increase employment from the clean electricity transition.

As shown in Figure 3, these minor cost increases result in negilgible changes to the least-cost configuration for the electricity grid in 2030. Study scenarios would still achieve clean electricity deployment around 80 percent clean by 2030, and it would only cost 4 percent more to achieve prevailing wages in the wind and solar industries and to manufacture 100 percent of components in the U.S. This is well within the margin of error for various models' predictions of wind and solar cost declines by 2030, as well as the cost savings induced by extension of existing tax credits for clean energy resources as outlined in the AJP and current federal legislation.

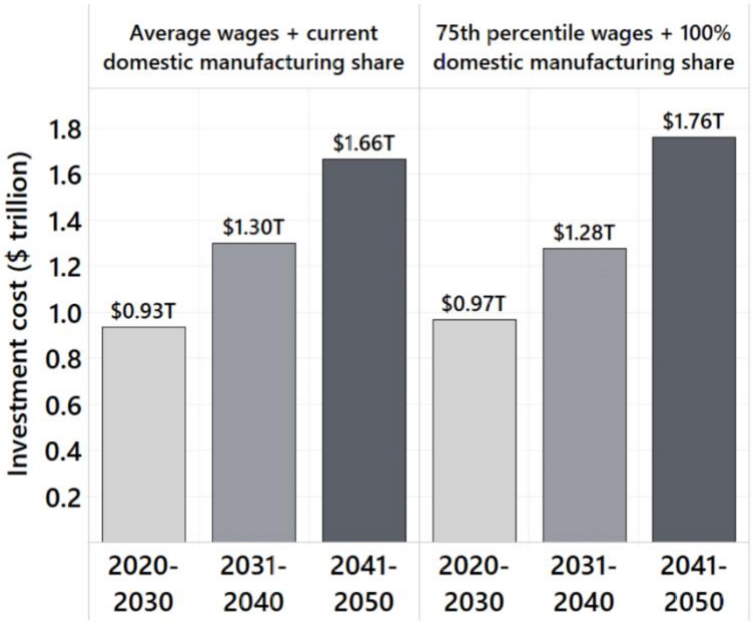

Figure 3. Comparative impacts of wages and percentage of domestic manufacturing of wind and solar on the investment cost required for nearly 80 percent clean energy by 2030. Source: Erin Mayfield and Jesse Jenkins, Influence of high road labor policies and practices on renewable energy costs, decarbonization pathways, and labor outcomes, Princeton University, 2021 (not yet published), 13.

An 80 percent by 2030 CES could provide significant opportunities for employment at prevailing wages in rural America and coal communities, while also helping to revitalize domestic manufacturing and jumpstart our economy.

PUBLIC HEALTH

AN 80 PERCENT BY 2030 CES, COMBINED WITH BENEFICIAL ELECTRIFICATION, DRAMATICALLY REDUCES AIR POLLUTION, IMPROVES PUBLIC HEALTH, AND ENSURES ENVIRONMENTAL JUSTICE

More than 135 million people in the U.S., or four people out of ten, breathe unhealthy air based on levels of pollution where they live.[25] Researchers estimate that exposure to pollution, especially fine particulate matter, is responsible for more than 100,000 premature deaths each year.[26] The burning of fossil fuels releases harmful pollutants that cause a wide array of negative impacts on human health and that disproportionally burden communities of color.[27] The 2030 Report finds that adopting an 80 percent by 2030 CES would help avoid more than $1.7 trillion in health and environmental costs, including 93,000 avoided premature deaths, through 2050.[28] Power sector decarbonization and transportation electrification together avoid more than 240,000 premature deaths and $3 trillion in environmental costs by 2050. Other analyses find similar widespread public health benefits, justifying swift action to adopt and implement a national CES.

Pollution from fossil fuel extraction and combustion harms public health

Despite recent laudable progress in reducing public health impacts of fossil power plants, the remaining 235 active coal power plants in the U.S. continue to harm the health of the communities around them.[29] The burning of fossil fuels, particularly coal, to produce electricity releases a wide array of harmful pollutants, including particulate matter, nitrogen dioxide, sulfur dioxide, mercury, and lead, causing 3,100 premature deaths in 2020.[30] Data shows air pollution has actually increased by as much as 5.5 percent in recent years, raising air pollution-related mortality[31] and contributing to the severity of COVID-19 cases.[32] These impacts are not borne equally in the U.S. Black Americans are exposed to 1.5 times more particulate pollution than Whites, regardless of income, and all non-Whites are exposed to 1.3 times more pollution than Whites.[33]

Extracting fossil fuels to provide energy to homes and businesses also carries major health costs. Numerous public health studies have shown that people who live near oil and gas wells experience an increased incidence of childhood leukemia, asthma attacks, congenital heart defects, low birth weight, and preterm birth compared to people who do not live close to production wells.[34] Coal mines have polluted thousands of fresh water sources, destroyed hundreds of mountain summits, and taken hundreds of thousands of lives through black lung disease. Sludge and coal ash ponds lie near mines and power plants, and 91 percent of plants were contaminating groundwater with toxic substances at levels exceeding federal safe standards as of 2018.[35]

The health benefits of coal closures are immediate. Closing just a single coal-fired power plant in Louisville, Kentucky, led to a 55 percent reduction in local air pollution, and nearly 400 fewer hospital visits for asthma attacks one year after the plant's closure.[36] In California, closing eight

power plants between 2001 and 2011 led to a drop in preterm birth rates.[37] In Chicago, the closure of three coal-fired power plants led to a 12 percent reduction in emergency room visits for children ages 0-4.[38] The list goes on.

Clean energy is an effective public health measure

Given what we know about how the entire fossil fuel lifecycle harms human health, transitioning to clean electricity and supporting investments to remediate contaminated sites would immediately improve public health. Over the past 15 years, the transition to clean energy resources, like wind and solar, has substantially reduced power sector air pollutants and resulted in a 91 percent reduction in premature deaths from 38,000 to 3,100 in 2020, compared with prior business-as-usual projections.[39]

The 2030 Report similarly finds an 80 percent by 2030 CES, combined with accelerated transportation electrification, would reduce exposure to fine particulate matter and reduce nitrogen oxide and sulfur dioxide emissions by 96 percent and 99 percent, respectively. The analysis shows these reductions in air pollution could save $1.7 trillion in health and environmental costs, including 93,000 avoided premature deaths, through 2050.[40]

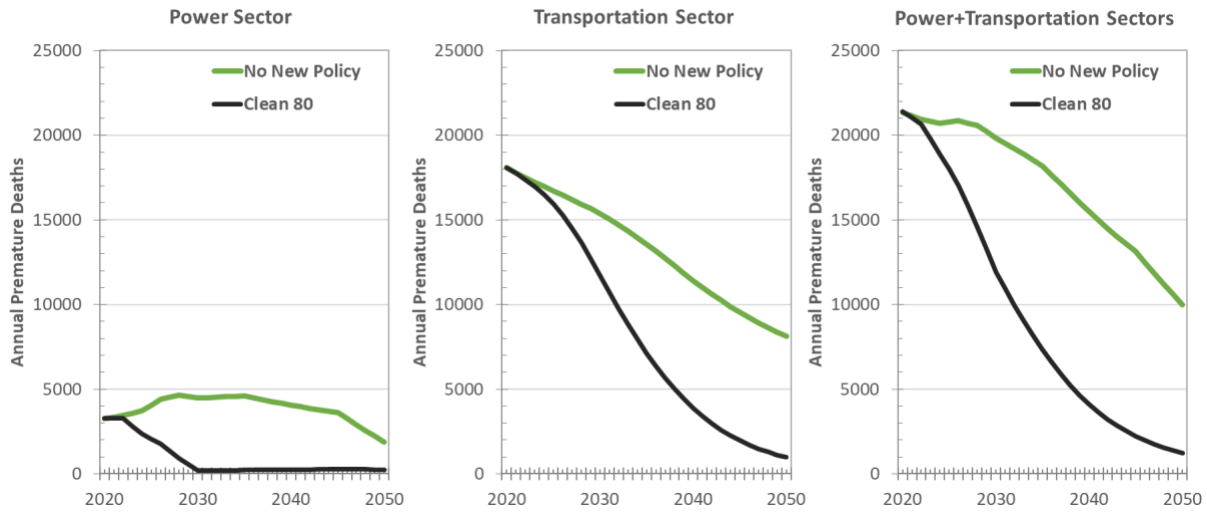

Figure 4. Annual premature deaths caused by air pollution from transportation and power sectors (individual and combined) in The 2030 Report 80 Percent Clean Scenario versus the No New Policy Scenario, 2020–2050. Source: The 2030 Report.

Other analyses support these findings. A policy scenario from Energy Innovation's Energy Policy Simulator similarly found that achieving net-zero emissions by 2050, including a 100 percent clean electricity grid, would avoid more than 45,000 premature deaths annually and 1.3 million asthma attacks every year by 2050.[41] The Princeton Net Zero America study finds that 200,000 to 300,000 cumulative premature deaths (representing $2 to $3 Trillion in estimated damages) would be avoided between 2020 and 2050 by transitioning transportation and the electric power sectors to meet an economy-wide target of net-zero emissions by 2050.[42]

The research and direct experiences of communities around the U.S. show that accelerating clean energy deployment and rapidly transitioning away from fossil fuels would save thousands of lives, improve quality of life for millions of Americans, and address historical environmental injustices. Though not found on customer bills, the health benefits of clean energy far outweigh any reasonable estimate of the cost of meeting an ambitious federal CES.

CLIMATE

AN 80 PERCENT BY 2030 CES WILL HELP SECURE A SAFE CLIMATE FUTURE, PUTTING AMERICA ON THE PATH TO ACHIEVE A CARBON-FREE ELECTRICITY SYSTEM IN 2035, AND NET-ZERO EMISSIONS BY 2050

The path to climate stability requires the U.S. to take meaningful policy actions this decade, and beyond, to reduce our outsized contribution to global greenhouse gas emissions (GHGs). According to the Intergovernmental Panel on Climate Change (IPCC), limiting global warming to 1.5°C above pre-industrial levels is necessary to avoid the worst effects of climate change. Ensuring limited-to-no-overshoot of this target requires that global net anthropogenic greenhouse gas emissions decline by about 45 percent[ii] from 2010 levels by 2030, and continue to decline thereafter, reaching net zero around 2050.[43]

As shown in Figure 5, The 2030 Report analysis finds that an 80 percent clean electricity grid and accelerated vehicle electrification by 2030 would reduce power and transport sector CO_2 emissions by 84 percent and 33 percent, respectively, from 2005 levels, thus reducing economy-wide emissions by more than 40 percent from 2005 levels by 2030. Several reputable peer-reviewed studies also find that implementing and achieving an 80 percent by 2030 CES would enable net-zero emissions economy-wide by 2050.

[ii] The IPCC Summary Report for Policymakers refers to a 40 percent to 60 percent interquartile range. These ranges reflect IPCC Scenarios P1 and P2, which do not rely on significant CO_2 removal in the latter half of the century.

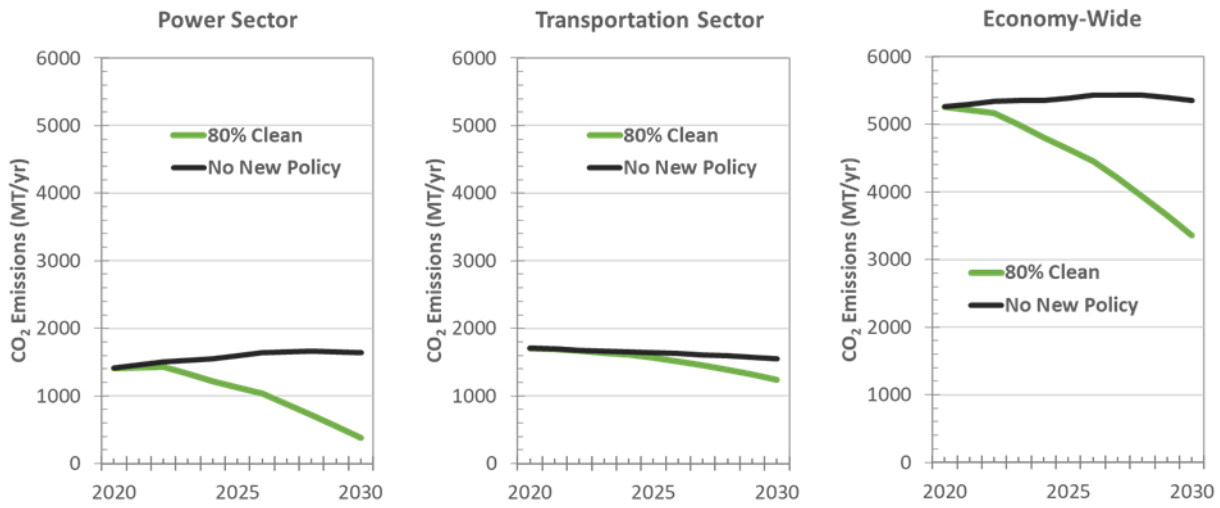

Figure 5. CO_2 emissions reductions from the power and transportation sectors (MT/year) in The 2030 Report 80 Percent Clean Scenario versus the No New Policy Scenario, 2020–2050. Source: The 2030 Report.

Immediate federal action is critical to ensuring that the U.S. cost-effectively reaches net-zero emissions in 2050. Unlocking deep emissions reductions economy-wide will require a clean, reliable, and carbon-free electricity grid, and the faster we get there, the less work must be done in other sectors in the near term. A CES is a promising policy option for achieving this nationwide and on a timeline congruent with the 1.5°C pathway.

An analysis conducted by Energy Innovation using the open-source Energy Policy Simulator (EPS) model shows that an 80 percent CES and retiring all coal by 2030 puts the U.S. on the path to achieve net-zero emissions in 2050 (see Figure 6). Energy Innovation's 1.5°C NDC for Climate Leadership cuts U.S. GHG emissions 50 percent in 2030 and achieves net-zero emissions in 2050, relative to 2005 levels. The CES modeled requires 80 percent clean electricity in 2030 and 100 percent in 2035, and it retires all coal by 2030.[iii]

[iii] The CES in the model assumes it is coupled with grid flexibility policies like expanded transmission and deployment of storage and demand response.

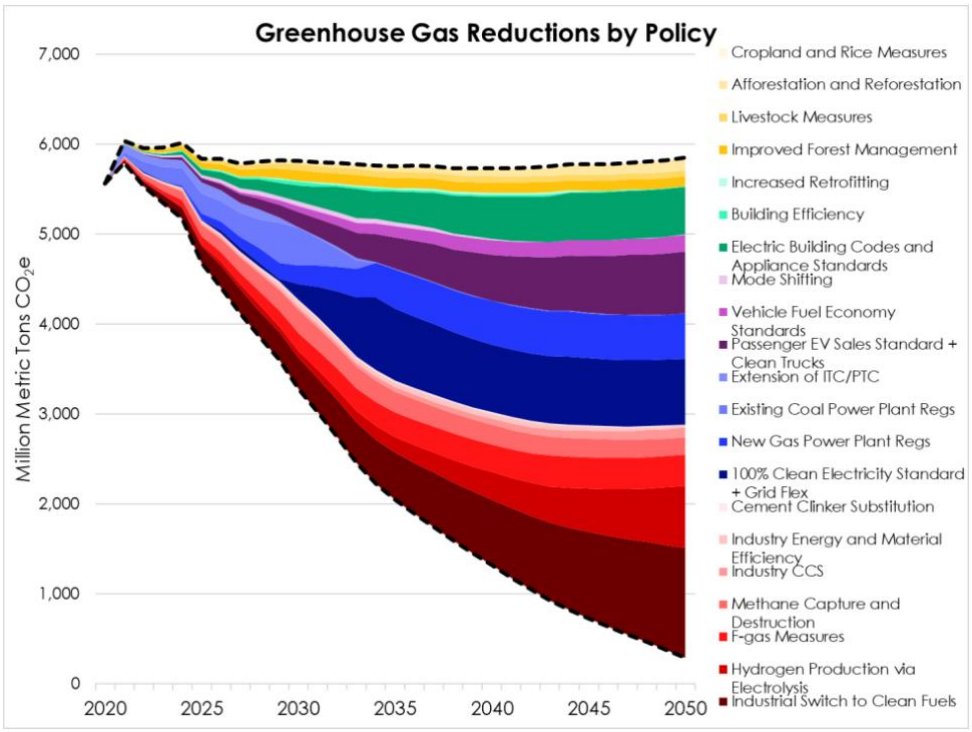

Figure 6. The wedge graph shows U.S. emissions trajectories, including how much each specific policy reduces emissions through 2050. Policies are color-coded by sector with industrial policies in red, electricity policies in blue, transportation policies in purple, building policies in green, LULUCF policies in yellow, and agricultural policies in orange. Source: Robbie Orvis & Megan Mahajan, A 1.5°C NDC for Climate Leadership for the United States, Energy Innovation, 4.

A key pathway to decarbonizing the transportation, building, and industry sectors is switching end uses in each sector to run on clean, carbon-free electricity (known as electrification), making a clean electricity system the "linchpin of economy-wide decarbonization."[44] As shown in Figure 6, the CES (dark blue) is integral to achieving the 1.5°C Scenario and net-zero emissions by 2050.

Another study conducted by the University of Maryland Center for Global Sustainability, World Resources Institute, and RMI shows that "a comprehensive strategy that layers ambitious federal action [including a CES] on top of state or other sub-national action can deliver up to 49% [emissions reductions] below 2005 levels by 2030."[45]

Finally, a study conducted by Princeton University evaluated five distinct technological decarbonization pathways for the U.S., reaching net-zero emissions by 2050. While the analysis is more policy agnostic, it finds that clean electricity is one of the six pillars needed to support the transition to net-zero.[46] The study's recommended policy actions include doubling carbon-free electricity sources from 37 percent today to 70 percent to 85 percent by 2030 and 98 percent to 100 percent by 2050 in all scenarios.[47]

The five reputable studies highlighted here clearly illustrate that a CES is a cornerstone policy to reach net-zero economy-wide emissions by midcentury. The power sector is the foundation of

the clean economy transition, and an 80 percent CES by 2030 would put the U.S. on the path to a safe climate future.

RELIABILITY

THE U.S. ELECTRICITY SYSTEM CAN CONTINUE TO OPERATE RELIABLY WITH 80 PERCENT CLEAN ELECTRICITY IN 2030, WHILE ALSO SUPPORTING ELECTRIFICATION OF TRANSPORTATION, BUILDINGS, AND INDUSTRY

The reliability of the U.S. electric power system is integral to economic vitality and societal well-being. As incidences of severe weather and other threats to the system increasingly affect the country's aging grid infrastructure, sustaining and enhancing grid reliability while boosting clean energy penetration on the grid remains a top priority. The long-held myth that renewable energy and energy storage produce grid instability is being dispelled as more research and real-world experiences demonstrate that renewable energy and energy storage in fact contribute to the stability and function of the electrical grid.[48] In addition, numerous analyses concur with The 2035 Report that an 80 percent clean grid would be reliable, even with rapid electrification.

As modeled in The 2030 Report, an 80 percent clean grid in 2030 is reliable and sufficient to meet demand in every hour of the year, while rapidly electrifying transportation and other sectors. To retain supply adequacy, The 2030 Report's 80% Clean case retains existing hydropower and nuclear capacity[iv] and much of the existing natural gas capacity, combined with new battery storage. All coal plants can be retired by 2030, and no new fossil fuel plants are needed.[49]

[iv] After accounting for already planned nuclear facility retirements.

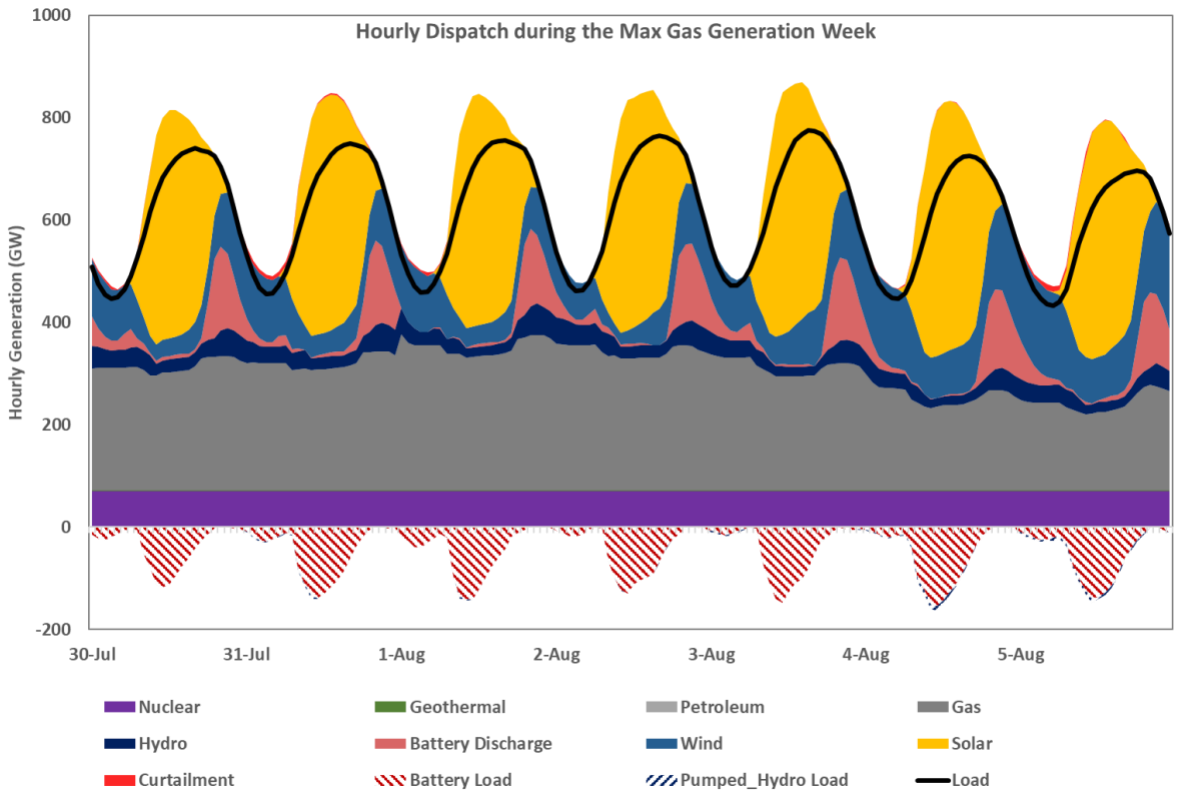

Figure 7. Hourly U.S. power system dispatch for extreme weather days in the 80% Clean case in 2030. Figure 7 details dispatch for the period of maximum natural gas generation, one week in late July and early August. Approximately 303 GW of natural gas is dispatched to meet demand on August 1, while renewables contribute significantly less generation than normal. Even when wind and solar generation drops to low levels, existing hydropower, nuclear power, and natural gas capacity, as well as new battery storage, are sufficient to maintain dependable system operations. Source: The 2030 Report.

A study from Vibrant Clean Energy on the value of transmission in a low-carbon grid found an 82 percent wind and solar grid could deliver reliable power by meeting electricity demand in every 5-minute period of the year in the Eastern U.S.[50] The study's WIS:dom model is the current state-of-the-art model for reliability analysis of weather-dependent electricity systems, examining multiple weather years with unparalleled granularity. The study also highlights that transmission plays an important role in maintaining adequate supply when wind and solar meet a majority of electricity needs. According to the study, "Expanding transmission is essential for cost-effectively integrating such high penetrations of wind and solar. A strong transmission network allows the primary wind-producing areas to export power when wind is abundant and import when it is not, just as the primary solar-producing areas export power during the day and import power at night."[51]

The Princeton Net Zero America Study scenarios reach 70 percent to 85 percent clean electricity by 2030, on a path to net-zero emissions in 2050, and finds grid reliability and supply adequacy in all scenarios with similar granularity as the modeling tools in The 2030 Report.[v]

Relying more heavily on renewable and energy storage for energy, capacity, and reliability services requires rethinking the way grids are planned and operated. Recent grid failures in Texas and polar vortex events in 2016 to 2019 point to reliability issues for systems too heavily reliant on natural gas[52] and coal.[53]

In addition, system operators in charge of maintaining reliability are not citing the transition to renewables as a threat to reliability. For example, the Midcontinent Independent System Operator (MISO), which runs the largest grid in the U.S., conducted its Renewable Integration Impact Assessment (RIIA) in 2021. The study found that while reaching 30 percent wind and solar penetration can be managed by refining current practices, getting beyond that threshold level "is not insurmountable and will require transformational change in planning, markets, and operations. Through coordinated action with MISO stakeholders, RIIA concludes that renewable penetration beyond 50 percent can be achieved."[54] (Emphasis added.) On top of nearly 20 percent zero carbon hydroelectric and nuclear power,[55] MISO's technical experts can already see a pathway for managing a system approaching 80% clean electricity.

The Southwest Power Pool (SPP), a smaller system operator in the Great Plains, already has wind energy as its largest resource, and concluded in a 2016 Wind Integration Study[56] that its transmission system could reliably handle up to 60 percent wind penetration. MISO and SPP's adjacent service territories and their combined experience with renewable integration have prompted a recent agreement to evaluate opportunities for joint transmission projects as a means to improve reliability and increase the value of renewables for their respective systems.[57]

As experience managing higher penetrations of renewables and energy storage on the grid increases, system operators and grid planners will gain greater familiarity with new tools and approaches for ensuring reliability. An 80 by 2030 CES will establish a needed milestone to expedite progress along the learning curve for those utilities less familiar with carbon-free resources, and established leaders will continue to demonstrate that a high-renewables grid does not threaten reliability.

[v] Electricity operations in the RIO model used by the Princeton study sampled 41 days in each year for operational feasibility, whereas the University of California, Berkeley study's PLEXOS model examined system operations for every hour in 7 different weather-years. Both used 1-hour increments.

AFFORDABILITY

AN 80 PERCENT CLEAN ELECTRICITY SYSTEM WILL NOT INCREASE WHOLESALE COSTS AND MAY EVEN LOWER CONSUMER ELECTRICITY BILLS

Since 2010, wind, solar, and battery storage costs have plummeted as these technologies have matured and their deployment on the grid has accelerated: wind energy costs have fallen 70 percent, while solar and battery costs have fallen 90 percent (see Figure 8). This trend is poised to continue, which means achieving 80 percent clean electricity will very likely provide cost savings over the coming decades. Combined with the additional economic and public health benefits of cleaner air and water, along with a stable climate, an 80 percent by 2030 CES is a no-regrets policy.

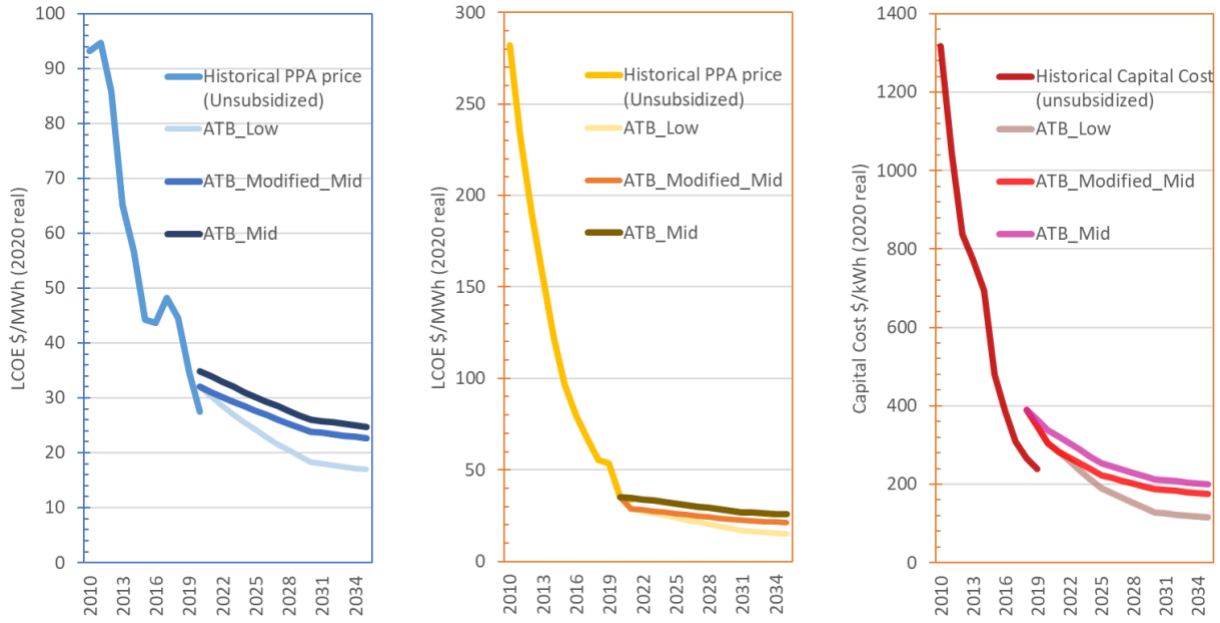

Figure 8. Levelized cost of energy (LCOE) for wind and solar, and battery storage capital costs, 2010-2020 (with projections through 2035). Source: The 2030 Report.

The 2030 Report finds the unsubsidized cost to generate and deliver electricity with an 80 percent CES is almost the same in 2030 as it is today, due in large part to low renewable energy and battery storage costs. Existing federal tax credits for wind and solar power plants will drive further cost declines. Modeling indicates extension of the tax credits, as outlined in the AJP, will make an 80 percent clean electricity grid cheaper than today's system.

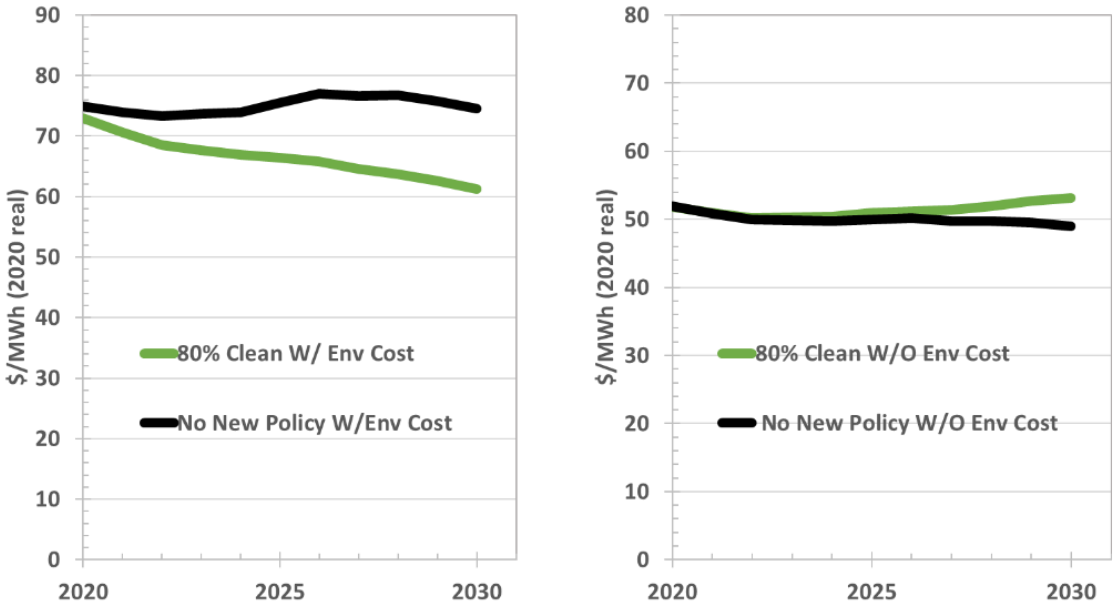

Figure 9. Cost ($/MWh) in 2020 real dollars of The 2030 Report 80 Percent Clean Scenario compared with the No New Policy Scenario. Source: The 2030 Report.

As the electricity grid decarbonizes, a proliferation of low-cost wind, solar, and battery storage will be built to meet an 80 percent CES. The pervasiveness of low-cost renewable energy and battery storage across the U.S. requires investment mainly in shorter transmission lines connecting renewable generation to existing high-capacity transmission lines or load centers. Relying on natural gas for only 20 percent of generation avoids large new investments for infrequently used capacity, helping to avoid major new stranded-asset costs. Retaining some natural gas generation averts the need to build excess renewable energy and long-duration storage capacity—helping achieve 80 percent clean electricity while keeping costs down. Though not studied in The 2030 Report, interregional transmission and increased deployment of distributed energy resources, demand response, and energy efficiency measures can further reduce costs by avoiding the need for extra storage and gas, while simultaneously improving reliability and resilience.

The 80 percent Clean Scenario results in wholesale electricity costs that are 2 percent cheaper than 2020 wholesale costs. This comparison does *not* account for the additional value of emissions reductions or avoided health costs. When health and environmental externalities are included, wholesale electricity prices in the 80 percent Clean case are 31 percent lower than in the No New Policy case. If direct-pay incentives, such as those identified in the AJP, are included, wholesale electricity costs fall 6 percent by 2030.

These findings are consistent with historical trends in technological innovation and clean energy policy that have led to unexpected low renewable costs and significant reductions in electricity sector emissions. According to a Lawrence Berkeley National Laboratory analysis, while the electricity sector reduced carbon emissions 40 percent since 2005, retail electricity prices in 2020 stayed flat.

As shown in Figure 10, total customer electricity bills in 2005 and 2020 were similar, and 2020 bills were 18 percent lower than projected, even as we reduced carbon 52 percent more than had been projected in 2005.[58] Meanwhile, reduced human health impacts saved hundreds of billions in health costs.

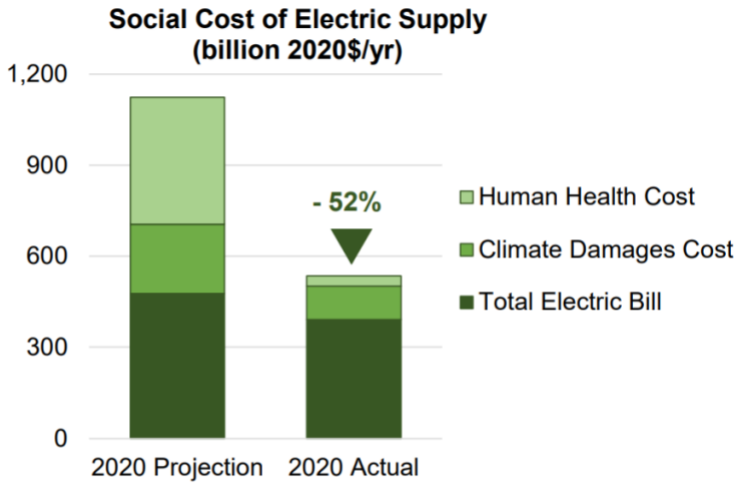

Figure 10. Social Cost of Electric Supply, 2020 projections made in 2005 compared to 2020 actual costs. Source: Ryan Wiser, Halfway to Zero, Lawrence Berkeley National Laboratory, April 2021, ii-iii.

In a 2020 study, Vibrant Clean Energy found that consistent decarbonization of the Eastern U.S. grid interconnection and robust high-voltage interregional transmission expansion led to consistent cost declines.[59,60] By 2040, the study's high-wind, high-carbon price scenario led to a 79 percent clean electricity system, along with 19 percent cost reductions from 2020 (see Figure 11). Like The 2030 Report, Vibrant Clean Energy assumes cost declines for renewable energy given today's low costs and historical trends.

FEASIBILITY

AN 80 PERCENT BY 2030 CES IS FEASIBLE EVEN WITH SCALED TRANSPORTATION AND BUILDING ELECTRIFICATION; IT REQUIRES RAPID BUT NOT UNPRECEDENTED INFRASTRUCTURE BUILD-OUT

Roughly doubling the share of carbon-free energy on the electricity grid from 40 percent today to 80 percent in 2030 might seem formidable, but the U.S. has done big things before. As White House Senior Advisor for Climate Policy and Innovation Sonia Aggarwal noted in *The New York Times*, "When Franklin D. Roosevelt became president in 1933, most of rural America still had no electricity. In 1935, he created the Rural Electrification Administration, and in just five years the nation built 250,000 miles of power lines and hooked up nearly a million farms. By the early 1950s, virtually the entire country had electricity."[61]

And the U.S. has made remarkable progress in the last 15 years. As the Halfway to Zero analysis from Lawrence Berkeley National Laboratory aptly highlights, we are already halfway to a carbon-free power sector, having reduced emissions 52 percent below business as usual since 2005.[62] With declining costs and strong market growth in wind, solar, and battery storage, we can continue apace to reach an 80 percent clean system by 2030, which corresponds to an 84 percent emissions drop from 2005 levels. Of note, major investor-owned electric utilities including Xcel Energy, AEP, and MidAmerican have already committed to reducing carbon emissions at least 80 percent by 2030.[63]

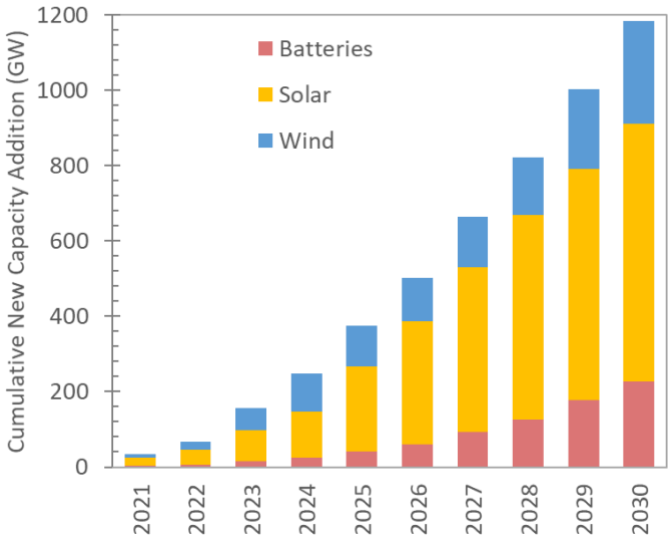

Figure 11. Cumulative new capacity of wind, solar, and battery storage to meet an 80 percent by 2030 CES, with high electrification. Source: The 2030 Report.

To achieve an 80 percent clean grid with scaled electrification of transportation and buildings will require roughly 950 gigawatts (GW) of wind and solar to be built, sited, and connected into the existing grid over the forthcoming decade—that's 95 GW annually for ten years. This pace would roughly triple U.S. historical maximum deployment, which occurred in 2020. Though such a pace is unprecedented in the U.S., China already exceeded this annual deployment rate in 2020 with 120 GW, demonstrating its technical feasibility.[64]

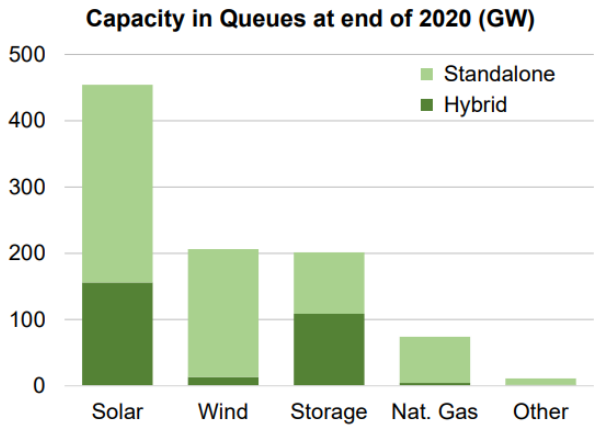

Figure 12. Solar, wind, storage, and natural gas capacity (in GW) in interconnection queues at the end of 2020. Source: Ryan Wiser, Halfway to Zero, Lawrence Berkeley National Laboratory, April 2021.

At least half of this generation has already been proposed by the private sector—over 660 GW of wind, solar, and batteries sits in existing generation interconnection queues (see Figure 12). Renewable energy supply is therefore not a binding constraint. Instead, the challenge of building an 80 percent clean electricity grid by 2030 lies in siting and connecting these resources to the grid fast enough to take advantage of the low-cost clean power.

As the level of weather-dependent wind and solar resources increases, the need for flexible resources, particularly storage, also increases. An 80 percent by 2030 CES requires roughly 220 GW of battery storage, and relies on 300 GW of natural gas capacity to provide adequate power to match demand in every hour of the year. Based on the findings of The 2030 Report, storage needs from 2021 to 2025 are more modest (only 41 GW, or 8 GW/year need to be built). This grows to 36 GW/year in the latter years (2026-2030). A federal tax incentive for battery storage would go a long way in promoting early growth of the storage market to meet the needs of an 80 percent by 2030 CES.

Other analyses present similar pictures of what it will take to rapidly decarbonize the U.S. electricity system. The Princeton Net Zero America Study finds a total of 850 GW of solar, onshore wind, and offshore wind would be needed in a high electrification scenario by 2030.[65] Princeton's study finds that sufficient land is available—324 GW of solar would use 1 percent of available land, onshore wind 16 percent, and offshore wind 4 percent. It also finds significant transmission would be needed—a 76 percent increase from 2020, implying $530 billion in investments from 2020 to 2030.[66]

Another analysis from University of California, Berkeley, GridLab, and Energy Innovation shows that the grid is capable of meeting demand under a high-electrification scenario, supported by a 90 percent clean grid (see Figure 13). The growth projections from this study are in line with historical growth in the U.S.—electrification requires electricity generation to increase approximately 2 percent per year, consistent with the 2.6 percent average historical growth in the electricity sector between 1975 and 2005.[vi] In other words, electrification alongside an 80 percent by 2030 CES will not require unprecedented growth.

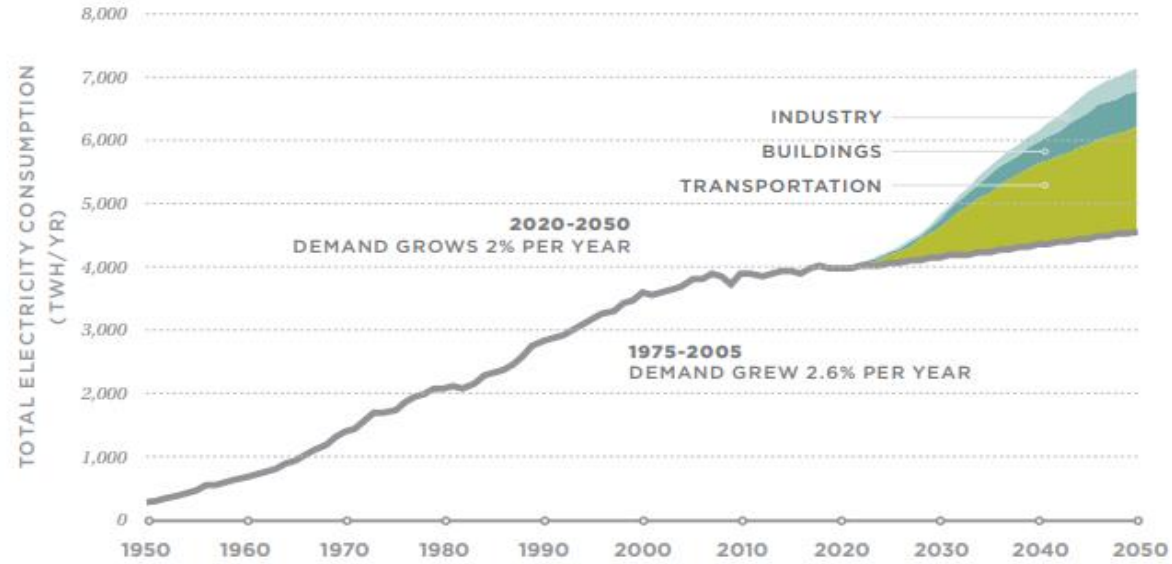

Figure 13. Historical and average annual U.S. electricity demand growth in the DRIVE Clean scenario, 2020-2050. Source: Amol Phadke, Nikit Abhyankar, et al., 2035 Report 2.0, University of California, Berkeley, GridLab, and Energy Innovation, April 21, vii.

The main challenge in achieving an 80 percent CES by 2030 is rapidly building out infrastructure in a difficult regulatory environment. Achieving this pace of infrastructure development requires new policy-reducing barriers to planning, siting, and interconnecting transmission and power plants. The AJP begins to address this need by investing $100 billion in new transmission projects and by establishing a new Grid Deployment Authority at the Department of Energy to reduce siting barriers. But greater congressional and agency action will still be needed. Congress should empower the Federal Energy Regulatory Commission to spur regional planning to improve access to high-quality renewable energy resources, allocate costs between regional utilities

[vi] The core demand scenario assumes we reach 100 percent electric vehicle sales for cars in 2030 and for medium- and heavy-duty trucks in 2035. It also assumes the "high electrification" scenario from the NREL Electrification Futures Study for buildings and industry. Mai, Trieu, et al., *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*, 2018, Golden, CO: National Renewable Energy Laboratory, NREL/TP-6A20-71500, https://www.nrel.gov/docs/fy18osti/71500.pdf.

benefitting from new transmission projects, and reform and streamline interconnection processes.

INNOVATION

AN 80 PERCENT BY 2030 CES WILL SPUR INNOVATION ON THE PATH TO 100 PERCENT AND FEDERAL INVESTMENTS CAN JUMPSTART DEPLOYMENT OF EMERGING CLEAN ENERGY TECHNOLOGIES

While the technology path to 80 percent CES by 2030 is clear, achieving 100 percent clean electricity by 2035 will require ambitious policy support to advance nascent generation technologies, transmission, flexible demand, and battery storage technologies. Although this goal will require targeted federal policy support through increased funding and innovation in the clean energy sector, numerous potential pathways exist for achieving the last 10-20 percent of clean energy generation cost-effectively.[67] Significant public- and private-sector efforts are underway to develop and deploy such technologies. Research, development, and deployment investments proposed in the AJP will likely accelerate such progress.

Clean energy technology has accelerated in performance and declined in cost far faster than experts have historically predicted, suggesting that the prospect for rapid advancement in new, 100 percent clean electricity technologies probably will arrive sooner than currently anticipated. A more ambitious 100 percent clean electricity target would likely spur significant technological innovation that could have large spillover benefits for climate mitigation and U.S. industrial, manufacturing, and technology leadership in related industries. An 80 percent target in the near term would have a similar effect—driving faster cost declines and innovation for renewable technologies and a portfolio of complementary resources.

An 80 percent to 90 percent clean grid is feasible using technologies that are already well established and commercially proven.

The 2035 2.0 Report used the latest renewable energy and battery storage prices to show that the U.S. can reach 90 percent clean electricity by 2035, dependably, with existing technologies, while rapidly electrifying transport. Advanced grid modeling used in the report explored one pathway to 90 percent clean electricity, suggesting the U.S. will need to add approximately 105 GW of new wind and solar plants and 30 GW of new battery storage each year by 2035.[68]

Pathways for achieving the last 10 to 20 percent of clean generation exist, but require innovation, financing, and new technology to improve performance and reduce costs.

Analysis by Energy Innovation and the University of California, Berkeley presents several pathways for achieving the last 10 percent of clean generation at a rate of approximately 9 to 13 cents/kWh, including through the use of green hydrogen, carbon capture, and direct air capture.[69] This would indicate overall average wholesale electricity rates of approximately 5 to 6 cents/kWh for 100 percent clean power, similar to today's average electricity rate of 5

cents/kWh. Three of the indicative supply-side pathways involve green hydrogen, which would be produced using zero-carbon electricity to split water via electrolysis. Low-cost renewable electricity and projected cost reductions in electrolyzers could lead to cost-effective green hydrogen. Two other pathways include carbon capture, and these costs are also projected to decline with demonstration and deployment. Importantly, the final 10 percent of clean generation is ripe for innovation, and numerous viable pathways exist beyond those considered in this analysis. Additional pathways, through the use of flexible nuclear, for example, may provide additional clean energy generation in the near future.

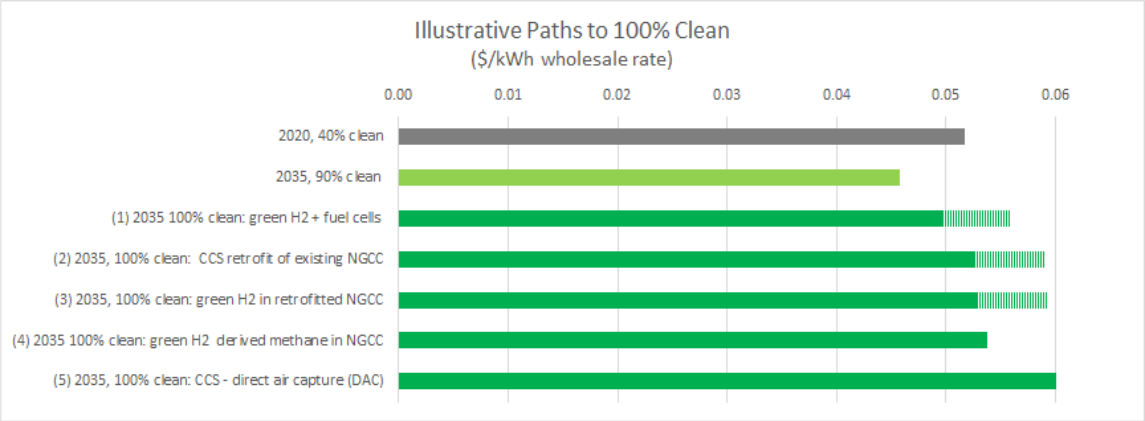

Figure 14. Wholesale electricity rates ($/kWh) for 100 percent clean by 2035. Source: Amol Phadke, Sonia Aggarwal, Mike O'Boyle, Eric Gimon, and Nikit Abhyankar, Illustrative Pathways to 100 Percent Zero Carbon Power by 2035 Without Increasing Customer Costs, Energy Innovation, September 2020.

Significant public- and private-sector efforts are underway to develop and deploy clean firm technologies.

Major U.S. utilities with aggressive decarbonization goals, such as the Los Angeles Department of Water and Power (LADWP), NextEra Energy, and Xcel Energy, have expressed interest and committed funding to green hydrogen projects. LADWP's planned 840 megawatt (MW) natural gas plant will run on 30 percent hydrogen on day one of operations beginning in 2025, with plans to run on 100 percent hydrogen by 2045. NextEra has proposed a $65 million pilot in Florida that will use a 20 MW electrolyzer to produce 100 percent green hydrogen from solar power, and blend the hydrogen with natural gas at an existing gas plant. Siemens Energy, a world leader in gas turbine manufacturing, already produces turbines that can run on at least 20 percent hydrogen, and it plans to have 100 percent hydrogen-compatible turbines by 2030. Meanwhile, Europe's latest hydrogen strategy calls for 6 GW of electrolyzers by 2024, scaling to 40 GW by 2030. Given that the continent has less than 1 GW of electrolyzers today, this will require a massive scale-up in a relatively short timeframe. The dramatic expansion in green hydrogen production, turbine technology, and electrolysis technology will help bring down costs and improve performance.

Direct air capture (DAC) of CO_2 is a nascent technology with the potential to scale and reduce costs significantly in the coming years. A recent techno-economic assessment of DAC found that demonstration projects could capture CO_2 at around $390/ton in today's costs.[70] The same study (supported by projections from Carbon Engineering) suggests that costs could drop below $200/ton with significant commercialization. The private sector, acting as first movers in the carbon capture space, are investing in high-cost DAC projects that will help commercialize nascent carbon removal methods and further drive down costs. Charm Industrial permanently sequestered 416 tons CO_2e for its first commercial customer, payment processing company Stripe, with additional forthcoming sequestrations.[71]

Finally, the Biden administration has called for substantial investment in climate mitigation research, development, and deployment. The U.S. Department of Energy recently committed $100 million in funding to support low-carbon technologies and launched a Climate Innovation Working Group to facilitate commercialization of DAC, battery storage, and other clean firm technologies. The administration has asked Congress to allocate even more funding to clean energy innovation, calling for the creation of an Advanced Research Projects Agency-Climate, as well as additional investments in R&D demonstration projects of DAC, storage, carbon capture, and other clean energy technologies.

Dedicated policy to support clean energy innovation and deployment is critical to ensure U.S. economic competitiveness and technology development.

As the rest of the world accelerates decarbonization efforts, the U.S. runs the risk of losing out on employment and economic gains from the development and deployment of critical clean energy technologies. Already, the U.S. is ceding leadership prowess in core technologies, including electrolysis, green hydrogen production, hydrogen distribution and combustion, and battery storage technologies. Failure to ramp up innovation and deployment in these sectors suggests that we may miss out on significant new job creation, economic growth, and technological advancement.

The time is ripe to jumpstart American innovation with robust policies and investments. With an increased focus on research and development and accelerated deployment, nascent clean energy technologies can scale more quickly, helping the U.S. thrive in a clean, electrified, carbon-free future.

[1] The White House, "Fact Sheet: The American Jobs Plan," March 31, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/.
[2] "Power Companies Urge Biden to Implement Policies to Cut Emissions 80 Percent by 2030," Reuters, April 19, 2021, https://www.reuters.com/business/energy/power-companies-urge-biden-implement-policies-cut-emissions-80-by-2030-2021-04-17/.
[3] "American Electric Power Company, Inc. (AEP) CEO Nick Akins on Q1 2021 Results - Earnings Call Transcript," Seeking Alpha, April 22, 2021. https://seekingalpha.com/article/4420741-american-electric-power-company-inc-aep-ceo-nick-akins-on-q1-2021-results-earnings-call.
[4] American Electric Power Company, Inc. (AEP) CEO Nick Akins on Q1 2021 Results - Earnings Call Transcript, April 22, 2020.
[5] U.S. Congress, House, CLEAN Future Act, H.R. 1512, 117th Congress, https://www.congress.gov/bill/117th-congress/house-bill/1512/text.
[6] Nikit Abhyankar, Umed Paliwal, Amol Phadke, Taylor McNair, David Wooley, Michael O'Boyle, 2030 Report: Powering America's Clean Economy: A Supplemental Analysis to the 2035 Report, Goldman School of Public Policy, University of California, Berkeley, GridLab, Energy Innovation LLC, April 2021.
[7] Christopher T.M. Clack, Michael Goggin, Aditya Choukulkar, Brianna Cote, & Sarah McKee, Consumer, Employment, and Environmental Benefits of Electricity Transmission Expansion in the Eastern U.S., Vibrant Clean Energy, October 2020, https://www.vibrantcleanenergy.com/wp-content/uploads/2020/10/EIC-Transmission-Decarb.pdf.
[8] Eric Larson, Chris Greig, Jesse Jenkins, Erin Mayfield, Andrew Pascale, Chuan Zhang, et al., Net-Zero America: Potential Pathways, Infrastructure, and Impact, Princeton University, December 15, 2020, https://netzeroamerica.princeton.edu/img/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf; Erin Mayfield and Jesse Jenkins, Influence of High Road Labor Policies and Practices on Renewable Energy Costs, Decarbonization Pathways, and Labor Outcomes, Princeton University, 2021 (not yet published), https://www.dropbox.com/sh/ad9pzifo9w1a49u/AAC2milGD44MlwXo1Sk7EAgsa?dl=0&preview=Working_Paper-High_Road_Labor_and_Renewable_Energy-PUBLIC_RELEASE-4-13-21.pdf.
[9] Ryan Wiser, Halfway to Zero: Progress Towards a Carbon-Free Power Sector, Lawrence Berkeley National Laboratory, Prepared for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, April 2021, https://eta-publications.lbl.gov/sites/default/files/halfway_to_zero_report.pdf.
[10] Robbie Orvis and Megan Mahajan, A 1.5°C NDC for Climate Leadership by the United States, April 2021, https://energyinnovation.org/wp-content/uploads/2021/04/A-1.5-C-Pathway-to-Climate-Leadership-for-The-United-States_NDC-update.pdf.
[11] E2, Clean Jobs America 2020: Repowering America's Economy in the Wake of COVID-19, April 2020, https://e2.org/reports/clean-jobs-america-2020/.
[12] E2, Clean Jobs America 2020, April 2020.
[13] Energy Futures Initiative and the National Association of State Energy Officials, The 2020 U.S. Energy & Employment Report, Fact Sheet, https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5e784c7fb0412f11a92ce04a/1584942208410/2020+USEER+Fact+Sheet.pdf.
[14] E2, Clean Jobs America 2020, April 2020.
[15] Chris Isidore, "Falling Sales, Job Losses and Bankruptcies: Pain Spreads Across Coal Country," CNN, December 9, 2020, https://www.cnn.com/2020/12/09/business/coal-country-pain/index.html.
[16] National Association of State Energy Officials and Energy Futures Initiative, 2020 U.S. Energy & Employment Report, https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5ee78423c6fcc20e01b83896/1592230956175/USEER+2020+0615.pdf, 69.
[17] Tyler Godwin, "US 2020 Coal Production Expected to Fall 26.2% on Year to 56-Year Low," S&P Global, November 10, 2020, https://www.spglobal.com/platts/en/market-insights/latest-news/coal/111020-us-2020-coal-production-expected-to-fall-262-on-year-to-56-year-low-eia.
[18] United Mine Workers of America, Preserving Coal Country: Keeping America's Coal Miners, Families and Communities Whole in an Era of Global Energy Transition, https://umwa.org/wp-content/uploads/2021/04/UMWA-Preserving-Coal-Country-2021-1.pdf.
[19] Larson et al., Net-Zero America, 296.
[20] Abhyankar et al., 2030 Report, 29.
[21] United Mine Workers of America, Preserving Coal Country.
[22] United Mine Workers of America, Preserving Coal Country.

[23] Mayfield and Jenkins, Influence of High Road Labor Policies and Practices on Renewable Energy Costs, Decarbonization Pathways, and Labor Outcomes, 15.
[24] Mayfield and Jenkins, 8.
[25] "More than 4 in 10 Americans Breathe Unhealthy Air, People of Color 3 Times as Likely to Live in Most Polluted Places," American Lung Association Press Release, April 21, 2021, https://www.lung.org/media/press-releases/sota-2021.
[26] Andrew L. Goodkind, Christopher W. Tessum, Jay S. Coggins, Jason D. Hill, and Julian D. Marshall, "Fine-Scale Damage Estimates of Particulate Matter Air Pollution Reveal Opportunities for Location-Specific Mitigation of Emissions," Proceedings of the National Academy of Sciences of the United States of America, April 30, 2019, Abstract, https://www.pnas.org/content/116/18/8775.
[27] Christopher W. Tessum et al., "Inequity in Consumption of Goods and Services Adds to Racial–Ethnic Disparities in Air Pollution Exposure," Proceedings of the National Academy of Sciences of the United States of America 116, no.3 (March 2019): 6001-6006, https://www.pnas.org/content/116/13/6001.
[28] Abhyankar et al., 2030 Report, 31.
[29] Clean Air Task Force, "Toll from Coal," https://www.tollfromcoal.org/#/map/(title:none//detail:none//map:none/US).
[30] Wiser, Halfway to Zero, iii.
[31] Karen Clay and Nicholas Z. Muller, Recent Increases in Air Pollution: Evidence and Implications for Mortality, Working Paper 26381, October 2019, https://www.nber.org/papers/w26381.
[32] Thomas Bourdrel et al., "The Impact of Outdoor Air Pollution on COVID-19: A Review of Evidence from in Vitro, Animal, and Human Studies," European Respiratory Review 30(2021): 200242, https://err.ersjournals.com/content/30/159/200242.
[33] Ihab Mikati et al., "Disparities in Distribution of Particulate Matter Emission Sources by Race and Poverty Status," American Journal of Public Health (April 2018), http://ajph.aphapublications.org/doi/abs/10.2105/AJPH.2017.304297.
[34] Anne C. Epstein, "Chapter Five - The Human Health Implications of Oil and Natural Gas Development," Advances in Chemical Pollution, Environmental Management and Protection 1 (2017): 113-145, https://www.sciencedirect.com/science/article/abs/pii/S2468928917300023.
[35] Earthjustice, "Mapping the Coal Ash Contamination," October 6, 2020, https://earthjustice.org/features/map-coal-ash-contaminated-sites.
[36] Joan Casey, "Asthma Hospitalizations Drop After Power Plants Reduce Emissions," Columbia Mailman School of Public Health, April 13, 2020, https://www.publichealth.columbia.edu/public-health-now/news/asthma-hospitalizations-drop-after-power-plants-reduce-emissions.
[37] Joan A. Casey et al., "Retirements of Coal and Oil Power Plants in California: Association With Reduced Preterm Birth Among Populations Nearby," American Journal of Epidemiology 187, no. 8 (August 2018): 1586-1594, https://academic.oup.com/aje/article/187/8/1586/4996680.
[38] Sarah Komisarow and Emily L. Pakhtigian, "The Effect of Coal-Fired Power Plant Closures on Emergency Department Visits for Asthma-Related Conditions Among 0- to 4-Year-Old Children in Chicago, 2009–2017," American Journal of Public Health (April 2021), https://ajph.aphapublications.org/doi/10.2105/AJPH.2021.306155.
[39] Wiser, Halfway to Zero, iii.
[40] Abhyankar et al., 2030 Report, 33.
[41] Orvis & Mahajan, A 1.5°C NDC for Climate Leadership by the United States, 2.
[42] Larson et al., Net-Zero America, 12.
[43] IPCC, Summary for Policymakers, in: Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty, 2018, https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf; and Recapturing U.S. Leadership on Climate: Setting an Ambitious and Credible Nationally Determined Contribution, Environmental Defense Fund, March 2021, 10, https://www.edf.org/sites/default/files/documents/Recapturing percent20U.S. percent20Leadership percent20on percent20Climate.pdf.
[44] Orvis & Mahajan, A 1.5°C NDC for Climate Leadership by the United States, 4.
[45] Nathan E. Hultman, Leon Clarke, Carla Frisch, Kevin Kennedy, et al., "Fusing subnational with national climate action is central to decarbonization: the case of the United States," Center for Global Sustainability, School of Public Policy, University of Maryland, Rocky Mountain Institute, and World Resources Institute, published in Nature Communications, October 16, 2020, 6, https://www.nature.com/articles/s41467-020-18903-w.pdf.
[46] Larson et al., Net-Zero America, 9.
[47] Larson et al., Net-Zero America, 87.
[48] See for e.g., "Renewables Rescue Stability as the Grid Loses Spin," National Renewable Energy Laboratory, September 15, 2020, https://www.nrel.gov/news/features/2020/renewables-rescue-stability-as-the-grid-loses-spin.html; and "NERC Report Highlights Major Contribution to Reliability Offered by Battery Storage," T&D World, February 11, 2021, https://www.tdworld.com/distributed-energy-resources/energy-storage/article/21154842/nerc-report-highlights-major-contribution-to-reliability-offered-by-battery-storage; and G. Van Horn, P. Allen, K. Voellmann, "Powering into the Future:

Renewable Energy & Grid Reliability," MJB&A, February 15, 2017, https://www.mjbradley.com/reports/powering-future-renewable-energy-grid-reliability.
[49] Abhyankar et al., 2030 Report, 28.
[50] Clack et al., Consumer, Employment, and Environmental Benefits of Electricity Transmission Expansion in the Eastern U.S., 4.
[51] Clack et al., Consumer, Employment, and Environmental Benefits of Electricity Transmission Expansion in the Eastern U.S., 18.
[52] Kevin Collier, "Fact Check: Renewable Energy Is Not to Blame for the Texas Energy Crisis, Natural Gas, the State's Dominant Energy Source, Has Provided Drastically Less Energy than Expected, According to Experts and Industry Data," NBC News, February 17, 2021, https://www.nbcnews.com/news/us-news/fact-check-renewable-energy-not-blame-texas-energy-crisis-n1258185.
[53] Robbie Orvis and Mike O'Boyle, "DOE Rulemaking Threatens to Destroy Wholesale Markets with No Tangible Benefit," Utility Dive, October 2, 2017, https://www.utilitydive.com/news/doe-rulemaking-threatens-to-destroy-wholesale-markets-with-no-tangible-bene/506289/.
[54] MISO's Renewable Integration Impact Assessment (RIIA), Summary Report, MISO, February 2021, 2, https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf.
[55] Potomac Economics, "2019 State of the Market Report for the MISO Electricity Markets," June 2020, 6, https://www.potomaceconomics.com/wp-content/uploads/2020/06/2019-MISO-SOM_Report_Final_6-16-20r1.pdf.
[56] 2016 Wind Integration Study, Southwest Power Pool, January 5, 2016, https://www.spp.org/documents/34200/2016 percent20wind percent20integration percent20study percent20(wis) percent20final.pdf.
[57] Derek Wingfield, "MISO and SPP to Conduct Joint Study Targeting Interconnection Challenges," Southwest Power Pool, September 14, 2020, https://spp.org/newsroom/press-releases/miso-and-spp-to-conduct-joint-study-targeting-interconnection-challenges/.
[58] Wiser, Halfway to Zero, ii-iii.
[59] Wiser, Halfway to Zero, ii-iii.
[60] Clack et al., Consumer, Employment, and Environmental Benefits of Electricity Transmission Expansion in the Eastern U.S.
[61] Justin Gillis and Sonia Aggarwal, "What Will It Take to Clean Up the Grid?" The New York Times, December 16, 2019, https://www.nytimes.com/2019/12/16/opinion/climate-change-grid.html.
[62] Wiser, Halfway to Zero.
[63] See for e.g., "Excel Energy Aims for Zero-Carbon Electricity by 2050," Xcel Energy, December 4, 2018, https://www.xcelenergy.com/company/media_room/news_releases/xcel_energy_aims_for_zero-carbon_electricity_by_2050; "A Clean Energy Future," American Electric Power, http://aepsustainability.com/environment/carbon/; Sophia Ptacek and Sheryl Carter, "More Utilities Make Big Commitments to Climate Action," NRDC Expert Blog, March 5, 2019, https://www.nrdc.org/experts/sophia-ptacek/more-utilities-make-big-commitments-climate-action.
[64] https://www.bloomberg.com/news/articles/2021-01-20/china-blows-past-clean-energy-record-with-extra-wind-capacity
[65] Princeton University, Net-Zero America: Potential Pathways, Infrastructure, and Impacts Interim Report, December 15, 2020, https://environmenthalfcentury.princeton.edu/sites/g/files/toruqf331/files/2020-12/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf.
[66] Larson et al., Net-Zero America, 140.
[67] Amol Phadke, Sonia Aggarwal, Mike O'Boyle, Eric Gimon, and Nikit Abhyankar, Illustrative Pathways To 100 Percent Zero Carbon Power By 2035 Without Increasing Customer Costs, Energy Innovation, September 2020, https://energyinnovation.org/wp-content/uploads/2020/09/Pathways-to-100-Zero-Carbon-Power-by-2035-Without-Increasing-Customer-Costs.pdf.
[68] Goldman School of Public Policy, The 2035 Report, April 2021, vi, http://www.2035report.com/transportation/wp-content/uploads/2020/05/2035Report2.0.pdf?hsCtaTracking=544e8e73-752a-40ee-b3a5-90e28d5f2e18%7C81c0077a-d01d-45b9-a338-fcaef78a20e7.
[69] Phadke et al., Illustrative Pathways To 100 Percent Zero Carbon Power By 2035 Without Increasing Customer Costs, 2.
[70] Mahdi Fasihi, Olga Efimova, et al., "Techno-Economic Assessment of CO2 Direct Air Capture Plants," Journal of Cleaner Production, July 1, 2019, https://www.sciencedirect.com/science/article/pii/S0959652619307772?via%3Dihub.
[71] Charm, "Charm Delivers Stripe's Carbon Removal Purchase Ahead-of-Schedule," April 20, 2021, https://charmindustrial.com/blog/2021/4/19/charm-announces-ahead-of-schedule-delivery-of-stripes-carbon-removal-purchase.