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THE NEW CLIMATE ECONOMY
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WORKING PAPER

AMERICA'S NEW CLIMATE ECONOMY: A COMPREHENSIVE GUIDE TO THE ECONOMIC BENEFITS OF CLIMATE POLICY IN THE UNITED STATES

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EXECUTIVE SUMMARY

Highlights

- The COVID-19 crisis emerged at a time when the U.S. low-carbon transition was experiencing significant momentum. Low-carbon technologies have become more affordable compared to fossil fuels, and U.S. clean energy investment and deployment have reached new heights.
- The impact of COVID-19 on the low-carbon transition has yet to be fully determined and will depend on how the federal government responds.
- This paper draws on the latest economic and policy research, which demonstrates that strong climate action and investments in low-carbon infrastructure can be effective ways to stimulate jobs and investment in the wake of the COVID-19 pandemic and secure the economy's long-term success.
- In contrast, delaying action on climate change will further expose the United States to costly damages from climate impacts, air pollution, and other public health crises.
- The United States can improve its manufacturing competitiveness by building a domestic market for low-carbon technologies and tapping into foreign markets. Moreover, climate action will help revitalize rural communities by diversifying their economies and providing affordable clean energy.
- The United States can ensure that climate policies are fair and equitable by supporting fossil fuel workers and communities, providing quality jobs, and ensuring the benefits are shared by all.

CONTENTS

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Progress Towards America's New Climate Economy

In recent years the United States has been growing its economy while reducing emissions. Although the COVID-19 pandemic is likely to cause a temporary decrease in U.S. emissions, an economic downturn is not the right kind of progress on climate change. The United States must work to combine emissions reductions with economic well-being, including domestic product (GDP), income, and economic equality. While more needs to be done, the evidence shows that this is possible. From 2005 to 2018, U.S. real GDP increased 25 percent[1] while energy-related carbon dioxide (CO_2) emissions fell 12 percent.[2] This is due to a combination of technological and policy factors, including the rapid deployment of renewable energy technologies, a shift from coal to gas in the power sector, and progress in vehicle emissions standards. Forty-one states and the District of Columbia have reduced their energy-related CO_2 emissions while increasing real economic growth between 2005 and 2017. This includes states in all major geographical regions. The states that are taking action on climate change as part of the U.S. Climate Alliance have grown their GDP per capita twice as fast and have reduced their emissions per capita faster than the rest of the country.[3]

Climate leadership from U.S. states, local governments, and businesses is laying a strong foundation, but it needs to be augmented with federal policies to achieve deeper long-term emissions reductions. U.S. states, cities, and counties that are committed to climate action in line with the Paris Agreement now represent almost 70 percent of U.S. GDP and population and more than half of U.S. emissions.[4] State and local climate leaders have implemented many impressive policies, including carbon pricing, renewable portfolio standards, energy efficiency resource standards, appliance efficiency standards, commitments to 100 percent clean electricity, and zero-emissions vehicle mandates. However, the administration of President Donald Trump is dismantling many existing federal policies, which makes it difficult for the country to truly reach a low-carbon economy and costs American consumers money. The rollback of vehicle fuel efficiency standards alone is expected to cost American drivers more than US$200 billion over the next 15 years.[5]

Low-carbon technologies are becoming more efficient and affordable for households and businesses. In the past decade, the costs of solar panels, wind turbines, LED bulbs, and lithium-ion batteries have fallen dramatically while performance has improved.[6] As low-carbon technologies have matured, they have become increasingly competitive with fossil fuel technologies, even without subsidies. Building new clean energy portfolios for power generation is now cheaper than keeping most existing coal plants in operation and is cheaper than building and operating most proposed gas-fired plants.[7,8] This has changed the calculus of many utilities. For example, PacifiCorp has proposed a plan to retire four coal units in Wyoming and replace them with a portfolio of wind, solar, and storage technologies, a move it says will save customers $248 million over the next 20 years.[9] Significant room exists to further bring down the costs of various low-carbon technologies. Electric cars and sport utility vehicles are already cheaper to operate than gasoline or diesel vehicles, and they are expected to reach purchase price parity during the mid-2020s.[10,11,12] Yet at the same time, many low-carbon technologies remain out of reach for low-income households, highlighting the need for an equitable transition to a low-carbon future.

Low-carbon investment is growing in the United States but needs to scale up significantly for the country to meet its climate goals. Addressing climate change will involve a massive shift of financial resources from carbon-intensive production and consumption to less-polluting, low-carbon alternatives. This shift has already begun. Banks and investors are increasingly using climate finance instruments like green bonds and are divesting from fossil fuels. BlackRock, the world's largest asset management firm, has committed to making sustainability and climate risks central to its investment strategy, signaling a turning point for the investment community. However, the need to accelerate investment in low-carbon technologies remains more urgent than ever before. Despite U.S. clean energy investment reaching a new high of $78.3 billion in 2019,[13] the United States still does not invest as much as China in renewable energy or electric transportation, and it has yet to commit significant resources to reducing emissions and increasing carbon sequestration in the heavy-duty transport, industrial, and land sectors. Meanwhile, COVID-19 is making it more difficult for clean energy projects to find financing. Without federal support—for example, extending federal tax credit deadlines for renewable projects—promising projects could fall apart.

The Economic Case for a New Climate Economy

In 2019, about 3.6 million Americans had clean energy jobs, and although many are threatened by the COVID-19 crisis, the sector is still set up for promising growth. In 2019 there were about 2.4 million U.S. jobs in energy efficiency, 266,000 in electric and alternative fuel vehicles, 248,000 in solar energy, 114,000 in wind energy, 108,000 in biofuels, and 66,000 in battery storage.[14] These jobs are well distributed all over the country and have been growing at a faster pace than overall employment. One study has indicated that clean energy and low-carbon jobs offer higher wages than the national average, and many are available to workers without college degrees, though there are important concerns about the lack of benefits like health care and lack of contract security.[15] Although it is too soon to tell the full impacts of COVID-19 on the economy, one study estimated that almost 600,000 clean energy workers lost their jobs in March and April 2020.[16] There are initial signs, though, that the renewable energy industry is weathering the crisis far better than fossil fuels. If this is true, and renewables receive appropriate government support, they could overcome the short-term shock and be in a better position in the future.[17]

With high unemployment, investing in clean energy and other low-carbon sectors as part of the economic recovery from the COVID-19 pandemic can be an effective way to create jobs in the near term. Economic research has found that whereas $1 million spent on renewable energy or energy efficiency in the United States generates about 7–8 full-time-equivalent jobs in the short to medium-term, $1 million spent on fossil fuels generates about 2–3 jobs.[18] In addition, investments in transit, pedestrian, and cycling projects have bigger employment impacts than investments in roads. For example, as part of the American Recovery and Reinvestment Act, each dollar spent on public transit projects created 70 percent more job hours than a dollar spent on highways.[19] Increasing plug-in electric vehicles (EVs) to 27 percent of U.S. vehicles on the roads in 2035 would generate approximately 52,000 additional net jobs per year and increase GDP by $6.6 billion per year on average from 2015 to 2040.[20]

Strong climate action is also consistent with long-term economic growth and a healthy job market. Many energy system and economic models find that the economic impacts of climate action will be minimal compared to the economy as a whole. These models find that with strong climate action, U.S. GDP will be between 0.7 percent lower and 0.6 percent higher compared to the baseline in 2030, and employment will be between 0.25 percent lower and 0.6 percent higher compared to the baseline in 2030. These models likely underestimate the benefits of climate action because they do not include the air quality benefits of climate action, the risks of economic damages without action, and the potential benefits of disruptive change. While these models were developed prior to the COVID-19 crisis, early research on the economic impacts of new U.S. stimulus spending estimates that large public investments of $320 billion per year in clean energy and agriculture programs could create 4.5 million gross jobs every year for 10 years. Likewise, $260 billion per year for upgrading infrastructure more broadly could create an additional 4.6 million gross jobs every year for 10 years. These investments would put the United States on track to reduce emissions in line with the Paris Agreement.[21]

Reducing fossil fuels and greenhouse gases to address climate change will also help address another public health scourge: air pollution. Fine particulate and ozone pollution are estimated to cause more than 100,000 premature deaths in the United States annually, with damages valued at around 4–5 percent of U.S GDP.[22,23] Recent research has indicated that people living in areas with poor air quality may be more susceptible to COVID-19, highlighting further interconnections between human and planetary health.[24] If the United States reduced emissions in a way consistent with the Paris Agreement, it would also decrease harmful air pollutants enough to prevent thousands of premature deaths per year while also reducing the impacts of future respiratory diseases on human health. In addition, natural climate solutions that preserve and restore natural and working lands have myriad benefits, including decreasing soil erosion and improving water availability and quality.[25]

On the other hand, if the United States does not act, the impacts of climate change could shave several percentage points off its GDP every year. Like the COVID-19 pandemic, climate change is a threat multiplier, and the earlier the United States responds, the easier it will be to limit the impacts. The cost of damages from extreme weather and climate disasters has been steadily increasing every decade as climate change makes these events more frequent and intense.[26] The hurricane in Puerto Rico in 2017 caused more than $90 billion in damages, wildfires in California in 2018–19 cost more than $40 billion, and flooding in the Midwest in 2019 cost more than $10 billion.[27] Without new policies, global mean temperature is expected to rise about 3.5°C by 2100,[28] which would lead to annual damages from climate change equal to around 1–3 percent of U.S. GDP by the end of the century.[29] In the worst case scenario, with rising emissions and limited or no adaptation, economic damages could reach 3.7–10.0 percent of GDP per year.[30] The South and parts of the Midwest will be the hardest hit, as will the poorest communities. Lowering emissions could greatly reduce these costs for all regions of the country.

The investments needed for low-carbon infrastructure are substantial but manageable, and economic recovery in the wake of the COVID-19 crisis presents an opportunity to speed up the low-carbon transition. Historically low interest rates provide an opportunity to accelerate private investments in low-carbon technologies in the near term. Over the longer term, the most conservative estimates suggest that the United States will need to increase its spending on energy systems by the equivalent of 2 percent of its GDP to transition to a low-carbon economy. Other estimates find that there may even be net savings since the savings on fossil fuel expenditures would outweigh the additional costs of low-carbon energy infrastructure.[31] Most estimates of the investment needs are using quite outdated technology cost assumptions, but clean energy costs are falling rapidly, making it even cheaper. Even if the additional spending for a low-carbon economy did reach the equivalent of 2 percent of GDP, that is well within the historical range; energy spending in the United States is at a low point now at around 6 percent of GDP but has fluctuated to as high as 13 percent.[32]

Renewing Economic Vitality in Key Sectors and Geographies

The United States can increase its competitiveness by innovating, engineering, and manufacturing low-carbon technologies. The domestic and global cleantech market has grown significantly in the last decade.[33] The U.S. advanced energy industry generated $238 billion in revenues in 2018, and the sector's 11 percent growth in 2018 was almost four times the growth of the U.S. economy overall.[34] COVID-19 has adversely impacted the U.S. manufacturing sector by shuttering factories and disrupting supply chains. Investment in low-carbon infrastructure as part of government-led stimulus can counteract some of the impact on manufacturing. Over the long run, it will enable U.S. manufacturing companies to incubate innovative products with massive growth potential at home and in emerging markets. At the same time, the emissions footprint of heavy industry must be addressed. Energy efficiency, electrification, green hydrogen, carbon capture, utilization, and storage all hold promise. Successfully developing and deploying clean manufacturing technologies like 3D printing, industrial Internet of Things, and smart connected devices would also curb energy use, reduce carbon pollution, and increase the sector's competitiveness.

While climate change presents a tremendous challenge for rural America, climate solutions can provide several economic benefits to these communities, helping to reduce the rural-urban divide. Rural households across America often pay higher energy prices than urban areas, but energy efficiency retrofits could save the average rural household hundreds of dollars annually.[35] Renewable energy can diversify the economies of rural communities, adding to the tax base and providing new streams of income for farming and ranching communities that host wind turbines or solar panels. Clean energy jobs account for a higher share of employment in rural areas than in urban areas, and they have been booming in recent years even as other job sectors are stalling. [36] Natural carbon capture in farms and forests has the potential to enhance productivity, profitability, and resilience.

Ensuring a Fair and Equitable Transition for All

Progress towards a new climate economy must be fair and equitable, ensuring that all Americans are able to share the economic benefits. In planning the COVID-19 recovery, there is significant opportunity to steer the United States on a path that ensures the new climate economy works for everyone, including those whose livelihoods are tied to high-carbon industries. For this to happen, governments at all levels, businesses and financial institutions, local communities, and environmental and labor organizations need to establish a comprehensive, fair transition framework to complement the low-carbon transition. Transitions are inevitably challenging. However, early planning, stakeholder involvement, and political and financial commitment can mitigate risks and create new opportunities. Ultimately, if the transition is managed well, it will reduce the immense human and economic costs of climate change, minimize disruptions from climate policies, and lead to a more sustainable and inclusive economy.

ABBREVIATIONS

APEC	Asia-Pacific Economic Cooperation
BLM	Bureau of Land Management
CO_2	carbon dioxide
CCUS	carbon capture, utilization, and storage
DOE	U.S. Department of Energy
EERS	energy efficiency resource standard
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EV	electric vehicle
HFC	hydrofluorocarbon
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
H_2	hydrogen
ICE	internal combustion engine
ITC	investment tax credit
kWh	kilowatt-hour
LCOE	levelized cost of electricity
LMI	low- and moderate-income
Mt	megaton
MW	megawatt
NCE	New Climate Economy
NDC	nationally determined contribution
PM	particulate matter
PTC	production tax credit
PV	photovoltaic
R&D	research and development
RGGI	Regional Greenhouse Gas Initiative
RPS	renewable portfolio standard
SMR	small modular reactor
TWh	terawatt-hour
UNEP	United Nations Environment Programme
WRI	World Resources Institute

1. INTRODUCTION

The COVID-19 crisis emerged at a time when the U.S. low-carbon transition was experiencing significant momentum. Low-carbon technologies have become more efficient and affordable compared to fossil fuel technologies, and U.S. clean energy investment and deployment have reached new heights. Business leaders and the global finance sector are waking up to the risks of investing in carbon-intensive activities and are making sustainability and climate risks central to their investment strategies. A growing wave of U.S. state and city policymakers are realizing that climate action is the only sustainable way forward for the U.S. economy and that robust economic development is compatible with reducing carbon emissions.

The COVID-19 pandemic has changed the economic environment for the low-carbon transition, just as it has for every other part of the economy. Clean energy businesses that were once rising fast are now shedding jobs in the thousands. Although carbon emissions for 2020 are projected to be significantly lower due to a decline in energy demand, this offers no cause for celebration in the face of the large-scale public health and economic crisis.

The long-term impact of COVID-19 on the low-carbon transition is uncertain. Much depends on how the crisis further unfolds and how U.S. policymakers choose to react. The low-carbon transition will receive a setback if the United States chooses to double down on investment in carbon-intensive sources. It also depends on whether the federal government chooses to bail out specific industry sectors with no strings attached or steers them towards a low-carbon path.

As the United States prioritizes economic recovery and job creation, it can do so in ways that simultaneously make progress in tackling the climate crisis, decoupling growth from emissions, and laying the building blocks for a sustainable future. In fact, a growing body of research reveals that America does not need to choose between decarbonization and economic growth. With the right policies and investments, it is possible to build a new climate economy that is low-carbon, sustainable, and socially inclusive. This new climate economy could stimulate job growth and innovation, save consumers and businesses money, restore American manufacturing competitiveness, and revive rural communities. Yet if climate change is not addressed, it poses real risks to America's economy. Like the COVID-19 pandemic, climate change is a threat multiplier, and the earlier the country responds, the easier it will be to limit the impacts.

This paper draws on the latest research to assess the progress that has been made and outlines the multiple reasons why decarbonization can benefit the U.S. economy, communities, and ecosystems, especially in today's economic reality. The low-carbon transition will not be easy, nor will it happen overnight, but it will be worth it. The aim of this paper is to present robust, systematic evidence of the socioeconomic benefits of decarbonization to reduce unfounded fears, unlock more climate policy support, and enable the mainstreaming of climate policy into other areas, such as economic development, infrastructure, finance, and energy.

The evidence presented in the paper is geared heavily towards energy production, energy efficiency, transportation, and industrial sectors. The natural resources and land sectors are mentioned briefly; further research should uncover the full extent of the transition that is happening in those areas, including the economic benefits generated from the transition.

This paper is organized as follows:

Section 2 charts the progress being made in the transition towards the new climate economy. This includes decoupling gross domestic product (GDP) growth from carbon emissions, accelerating the momentum of state and local policies, improving low-carbon technology, and increasing low-carbon investments.

Section 3 presents the broad economic case for climate action in the United States. It explains how existing climate policies are benefiting the economy and how further commitment to a low-carbon future could unlock new opportunities for jobs and economic growth. It highlights how reducing emissions can also benefit human health and ecosystems. It shows that decarbonizing America's economy is affordable but delaying action to address climate change is not.

Section 4 dives deeper into two specific areas where climate action can restore America's economic vitality. The first is how the United States could boost its manufacturing sector by becoming a leader in low-carbon innovation. The second is how climate action can reenergize rural America by relieving energy poverty and leveraging low-carbon technologies and solutions to promote rural economic development.

Section 5 explains how the United States can ensure that the low-carbon transition is equitable and fair for all Americans. This includes providing support for fossil fuel workers and communities and ensuring that the benefits of climate policies are shared by all.

2. CHARTING PROGRESS TOWARDS AMERICA'S NEW CLIMATE ECONOMY

The nationwide momentum towards a new climate economy is undeniable and gathering pace, even though the COVID-19 outbreak will cause disruptions for the rest of the year and will have reverberations beyond. In a post-COVID-19 world, it will be critically important that U.S. policymakers continue building upon the significant progress made towards the new climate economy rather than increasing U.S. dependence on fossil fuel production and use. The latter would risk slowing down the transition to a low-carbon future by locking in polluting infrastructure for decades.

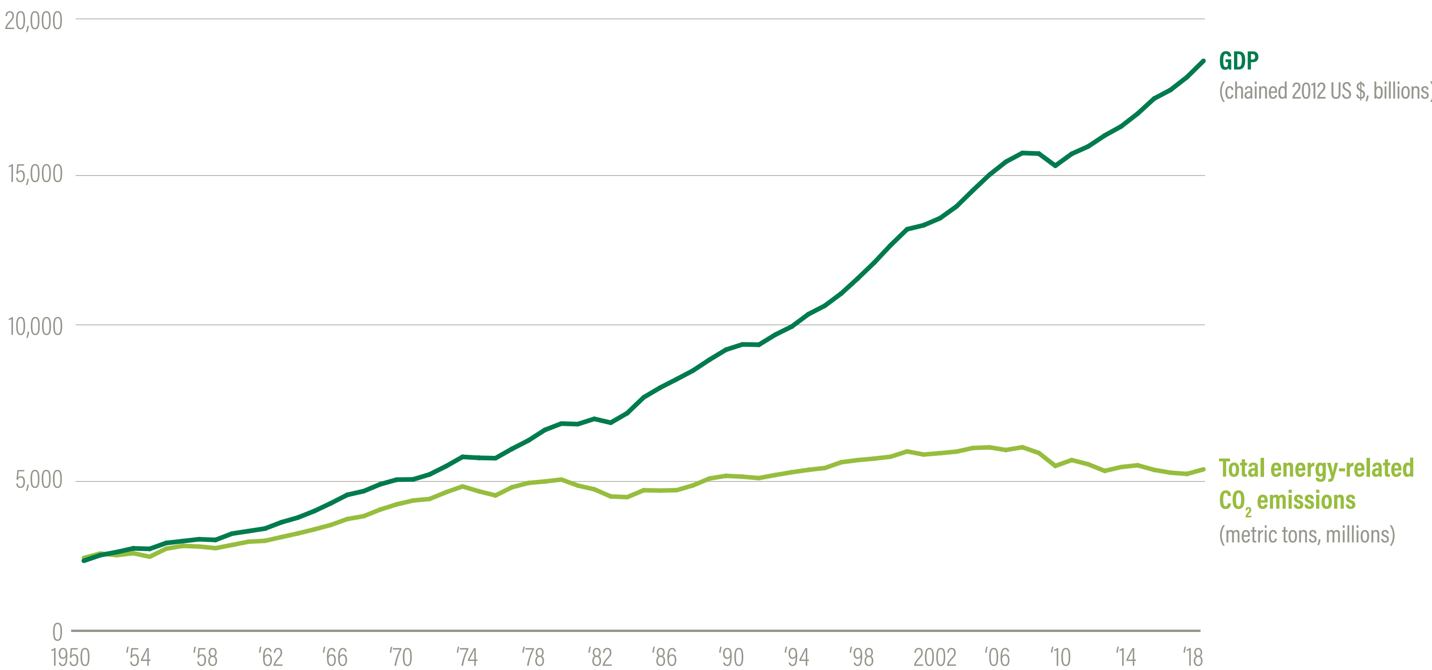
This section offers a look at the progress made towards America's new climate economy, especially during the past decade. No single report can hope to fully enumerate all facets of the transition from a high-carbon to a low-carbon economy. Rather, the objective here is to outline the broad contours of the transition. There is one caveat though: the discussion is focused more on the energy sector. Other areas, including the land sector and urban environments, are mentioned briefly.

Decoupling Economic Growth and Carbon Emissions

U.S. greenhouse gas (GHG) emissions are expected to drop in 2020 due to the COVID-19 pandemic. However, an emissions reduction as a result of a deadly virus and an economic downturn is not the kind of progress on climate change that is desirable. Furthermore, as the economy begins to recover from COVID-19, emissions are expected to return to business as usual. Going forward, the United States will need to reduce emissions while growing its economy.

Data from around the world and in the United States are increasingly showing that emissions reductions and economic growth are not only compatible but also complementary. In the United States, a combination of technological, market, and policy factors—including improvements in vehicle emissions standards, increases in lighting and appliance efficiency, a shift from coal to

Figure 1 | **U.S. GDP and CO_2 Emissions Are Decoupling**



Notes: CO_2 = carbon dioxide; GDP = gross domestic product.

Sources: U.S. Energy Information Administration. 2020. *Monthly Energy Review February 2020*. Washington, DC: U.S. Energy Information Administration, Office of Energy Statistics, U.S. Department of Energy. https://www.eia.gov/totalenergy/data/monthly/archive/00352002.pdf; Federal Reserve Economic Data. 2020. "Real Gross Domestic Product." Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/GDPC1.

natural gas in the power sector, the rapid deployment of wind and solar power, and the shift to a more service-based economy—has made it possible to increase GDP while decreasing GHG emissions. From 2005 to 2018, U.S. real GDP increased 25 percent while energy-related carbon dioxide (CO_2) emissions fell 12 percent (Figure 1).[37,38] During this period, both energy intensity (energy consumed per dollar of GDP) and carbon intensity (CO_2 produced per dollar of GDP) fell. This is not just a year here or there—this is sustained transformation of the world's largest economy. Of course, GDP is not the only indicator of a healthy economy. The United States should be aiming to reduce emissions while also improving real wages, worker conditions, and social equality.

Declining carbon intensity is good news for America's environment and economy, but much of the decline so far is due to fuel switching from coal to gas in the power sector.[39] Continued investment in gas infrastructure is, however, inconsistent with a low-carbon future and compounds risks for both investors and consumers due to intense competition from clean energy technologies. As coal plant retirements approach record highs, the challenge will be to displace electricity generated from gas with low-carbon resources to drive further reductions in carbon emissions from the power sector. This can be achieved by taking advantage of technological advances that have decreased the cost of renewable energy and battery storage technologies and further accelerating the deployment of other low-carbon technologies that are not yet widely used, such as carbon capture and green hydrogen.

The decoupling of emissions from GDP has also spread widely across U.S states, though the pace varies. Forty-one states and the District of Columbia have reduced their energy-related CO_2 emissions while increasing real economic growth between 2005 and 2017 (Figure 2). This includes states in all major geographical regions (Figure 3). Only nine states have not decoupled emissions from growth, with a handful of them witnessing a significant increase in emissions.

The states that are acting on climate change are often seeing the most substantial economic gains, such as the 25 members of the bipartisan U.S. Climate Alliance, which are committed to reducing carbon emissions consistent with the goals of the Paris Agreement. Between 2005 and

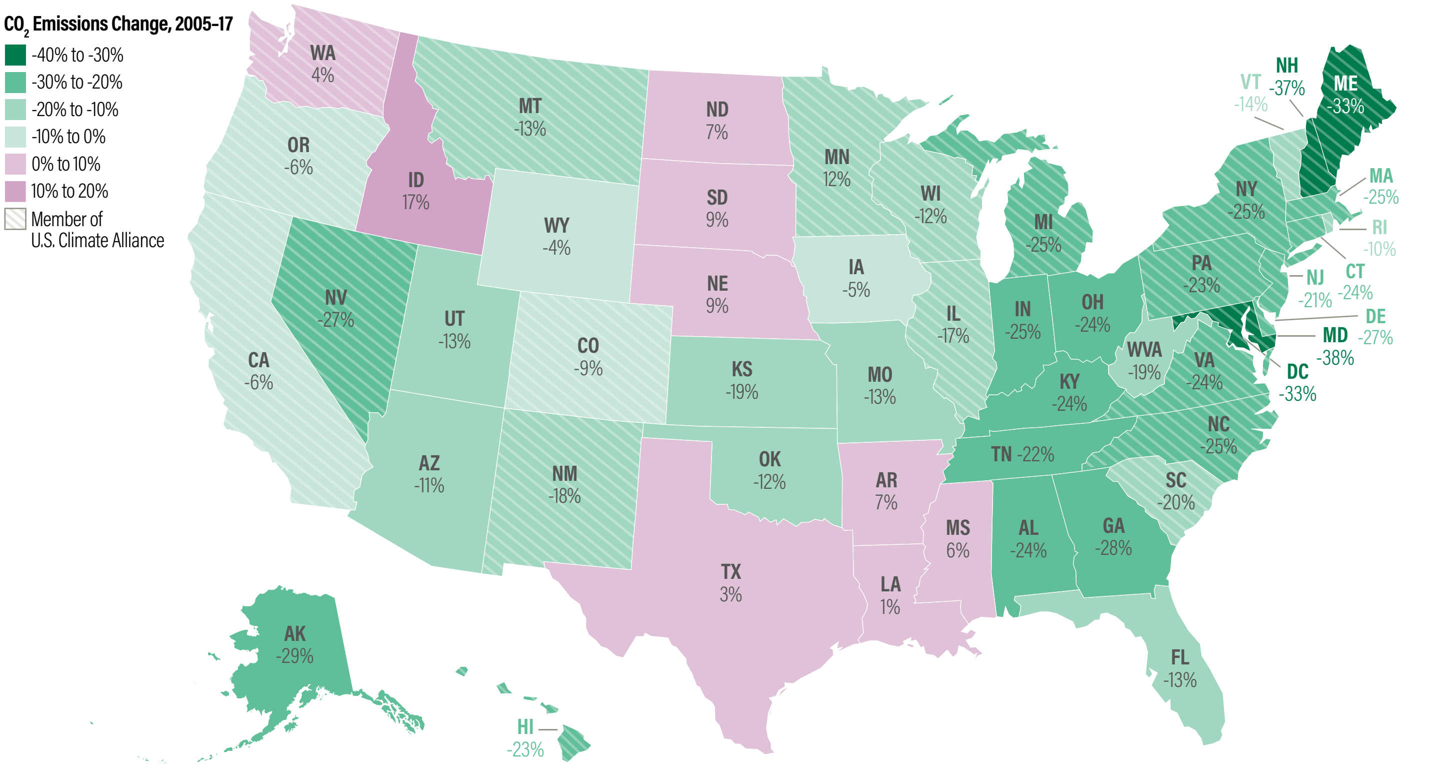
Figure 2 | Forty-One U.S. States and Washington, D.C., Are Decoupling GDP and CO_2 Emissions

	RANK	STATE	CHANGE IN EMISSIONS (2005-2017)	CHANGE IN GDP (2005-2017)
DECOUPLED STATES	1	Maryland	↓ -38%	↑ 18%
	2	New Hampshire	↓ -37%	↑ 15%
	3	District of Columbia	↓ -33%	↑ 21%
	4	Maine	↓ -33%	↑ 5%
	5	Alaska	↓ -29%	↑ 17%
	6	Georgia	↓ -28%	↑ 16%
	7	Nevada	↓ -27%	↑ 3%
	8	Delaware	↓ -27%	↑ 5%
	9	North Carolina	↓ -25%	↑ 19%
	10	Indiana	↓ -25%	↑ 13%
	11	New York	↓ -25%	↑ 21%
	12	Massachusetts	↓ -25%	↑ 26%
	13	Ohio	↓ -24%	↑ 9%
	14	Alabama	↓ -24%	↑ 6%
	15	Kentucky	↓ -24%	↑ 9%
	16	Connecticut	↓ -24%	↑ 0.5%
	17	Virginia	↓ -24%	↑ 12%
	18	Hawaii	↓ -23%	↑ 18%
	19	Pennsylvania	↓ -23%	↑ 18%
	20	Tennessee	↓ -22%	↑ 19%
	21	New Jersey	↓ -21%	↑ 6%
	22	Michigan	↓ -20%	↑ 2%
	23	South Carolina	↓ -20%	↑ 21%
	24	Kansas	↓ -19%	↑ 24%
	25	West Virginia	↓ -19%	↑ 7%
	26	New Mexico	↓ -18%	↑ 9%
	27	Illinois	↓ -17%	↑ 10%
	28	Vermont	↓ -14%	↑ 9%
	29	Missouri	↓ -13%	↑ 6%
	30	Montana	↓ -13%	↑ 21%
	31	Minnesota	↓ -13%	↑ 15%
	32	Utah	↓ -13%	↑ 40%
	33	Florida	↓ -13%	↑ 11%
	34	Oklahoma	↓ -13%	↑ 34%
	35	Wisconsin	↓ -12%	↑ 12%
	36	Arizona	↓ -11%	↑ 14%
	37	Rhode Island	↓ -10%	↑ 1%
	38	Colorado	↓ -9%	↑ 31%
	39	Oregon	↓ -6%	↑ 32%
	40	California	↓ -6%	↑ 31%
	41	Iowa	↓ -5%	↑ 17%
	42	Wyoming	↓ -4%	↑ 15%
NOT DECOUPLED STATES	43	Louisiana	↑ 1%	↓ -6%
	44	Texas	↑ 3%	↑ 45%
	45	Washington	↑ 4%	↑ 41%
	46	Mississippi	↑ 6%	↑ 7%
	47	Arkansas	↑ 7%	↑ 10%
	48	North Dakota	↑ 7%	↑ 75%
	49	South Dakota	↑ 9%	↑ 27%
	50	Nebraska	↑ 9%	↑ 27%
	51	Idaho	↑ 17%	↑ 22%

Notes: CO_2 = carbon dioxide; GDP = gross domestic product.

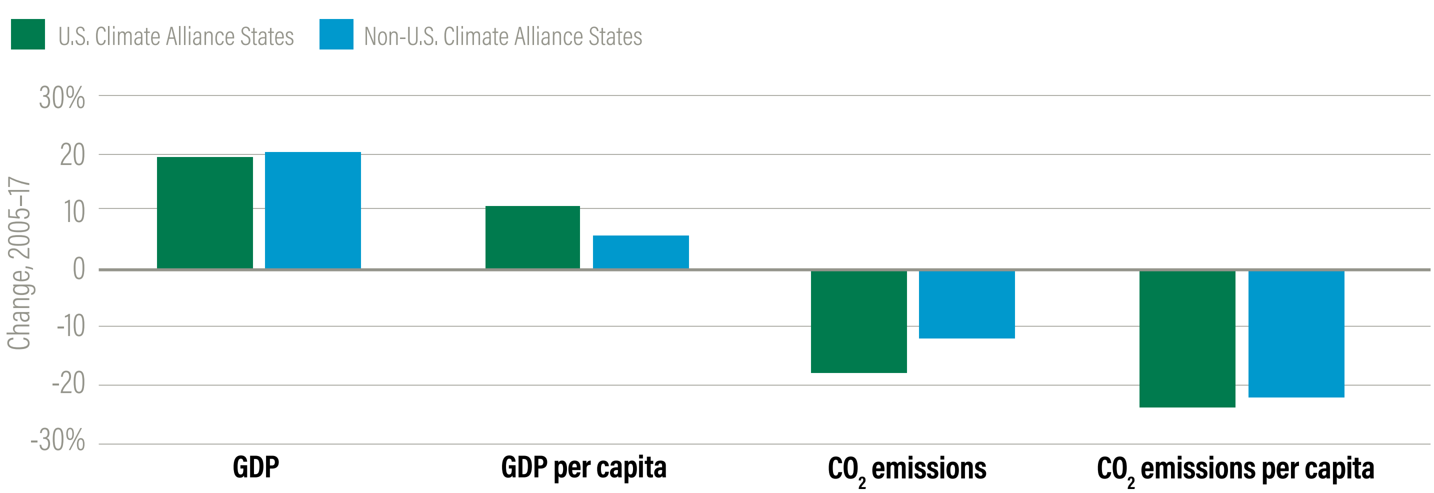
Sources: U.S. Energy Information Administration. 2019. "Energy-Related Carbon Dioxide Emissions by State, 2005-2017." February 27. https://www.eia.gov/environment/emissions/state/analysis/; Bureau of Economic Analysis. 2020. "Gross Domestic Product by State." https://www.bea.gov/data/gdp/gdp-state.

Figure 3 | CO_2 Emissions Change, 2005–17



Sources: U.S. Energy Information Administration. 2019. "Energy-Related Carbon Dioxide Emissions by State, 2005–2017." February 27. https://www.eia.gov/environment/emissions/state/analysis/; U.S. Climate Alliance. 2020. "Governors." http://www.usclimatealliance.org/governors-1.

Figure 4 | U.S. Climate Alliance States Lead the Country in Economic Growth and Emissions Reduction



Notes: CO_2 = carbon dioxide; GDP = gross domestic product.

Sources: U.S. Energy Information Administration. 2019. "Energy-Related Carbon Dioxide Emissions by State, 2005–2017." February 27. https://www.eia.gov/environment/emissions/state/analysis/; Bureau of Economic Analysis. 2020. "Gross Domestic Product by State." https://www.bea.gov/data/gdp/gdp-state; US Census Bureau. 2019. "State Population Totals and Components: 2010–2019." December 30. https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html; US Census Bureau. 2016. "State Intercensal Tables: 2000–2010." November 30. https://www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-state.html.

2017, U.S. Climate Alliance member states and territories reduced their per capita CO_2 emissions faster than the rest of the country and grew their per capita GDP twice as fast as the rest of the country (see Figure 4).[40]

Emissions reductions will have to accelerate in the next decade. For the world to be on a trajectory that limits global warming to 2°C, as called for in the Paris Agreement, the United States needs to reduce net emissions 40–45 percent below 2005 levels by 2030 and 80–90 percent below 2005 levels by 2050. To be on track for 1.5°C of warming, the Paris Agreement's more stringent target, the United States needs to reduce net emissions 45–50 percent below 2005 levels by 2030 and to zero by 2050.[41] This means that from 2018 to 2030, U.S. emissions will have to decrease more than twice as fast as they did during 2005–18.

To achieve these deep emissions cuts while continuing economic growth will require a significant change in U.S. climate policy in the near term as well as a diverse array of policy solutions to bring about fundamental shifts in the way Americans power their homes and businesses, produce goods, transport people and goods, and manage their lands. Driving this shift across all sectors of the economy will necessitate an all-in effort from both the public and private sectors. Governments at all levels will need to set goals and standards, provide market signals and incentives, utilize their procurement power, and invest public resources. The private sector, for its part, will need to rethink its business models and unleash its entrepreneurial and technological energies.

Technology Improvements and the Falling Costs of Low-Carbon Technologies

American ingenuity has unlocked innovative solutions in a variety of strategic areas, including defense, health, agriculture, and information technology, to name a few. That same spirit is now propelling the transition to America's new climate economy. Many clean energy technologies were limited to niche markets just a decade ago. Today, the rapid deployment of solar, wind, batteries, electric vehicles (EVs), and energy efficiency technologies provides a glimpse of what is possible in the transition to a low-carbon economy.

Nearly every segment of the low-carbon market is experiencing rapid price declines as a result of technological advancements and market deployment. Since 2010, the benchmark levelized cost of electricity per megawatt-hour has fallen 84 percent for solar photovoltaic (PV), 49 percent for onshore wind, and 56 percent for offshore wind.[42] Technology advances are also delivering substantial cost reductions for batteries, which determine the cost of EVs and the ability of battery storage projects paired with renewable energy to compete with traditional generation in electricity markets. Average market prices for battery packs have plunged from US$1,100 per kilowatt-hour (kWh) in 2010 to $156/kWh in 2019, an 87 percent fall in real terms, propelling interest in energy storage like never before.[43] Prices are projected to further fall to $100/kWh by 2023, enabling ever higher penetrations of renewable electricity and propelling vehicle electrification.[44]

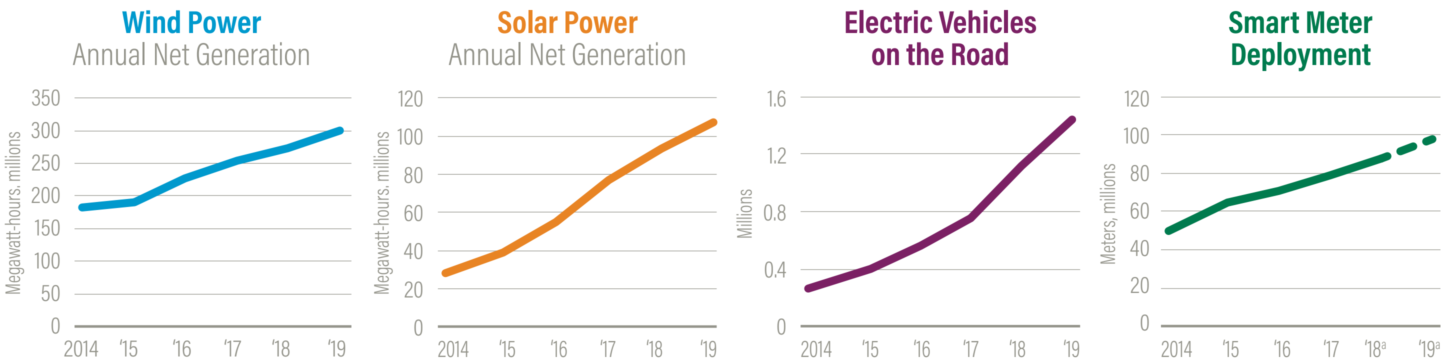
Technological advances are also making low-carbon technologies more efficient. Solar panel manufacturers, for instance, have been engaged in a race to the top in terms of solar cell efficiency.[45] Similar improvements are happening in wind technology, with turbines continuing to grow in size to optimize the cost and performance of wind projects.[46] General Electric's Haliade-X wind turbine—the largest and most powerful offshore wind turbine produced to date, with 350-foot-long blades and 12 megawatt (MW) output—will be deployed in Maryland and New Jersey between 2022 and 2024.[47] Recent years have also seen rapid progress in long-range EVs. The median EV range has increased 71 percent in seven years, from 73 miles in 2011 to 125 miles in 2018.[48] The best-selling model, the Tesla Model 3, has a range of over 250 miles. For the 2020 model year, at least 10 models have a range greater than 200 miles, and a few of them, including the Nissan Leaf Plus and the Hyundai Kona Electric, are priced under $30,000 after using the one-time $7,500 federal tax credit.[49] These technological improvements will only continue over the coming years.

Enabled by these technology improvements and cost declines, the United States has seen rapid deployment of several low-carbon technologies over the last decade (see Figure 5):

Solar energy generation has experienced an average annual growth rate of 50 percent in the past decade, and total solar capacity installed nationwide stands at 71 gigawatts (GW).[50] Solar has increased its share of total U.S. electricity generation from just 0.1 percent in 2010 to more than 2.5 percent today, enough to power 13.5 million homes.[51] The growth in renewable energy has been faster than U.S. government scenarios projected (see Box 1).

U.S. wind power has more than tripled over the past decade and reached over 100 GW of total operating

Figure 5 | **The Growth in Deployment of Low-Carbon Technologies in the United States**



Note: a. Projections.

Sources: U.S. Energy Information Administration. 2020. "Electric Power Monthly: Data for March 2020." May 26. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_01_a; Alternative Fuels Data Center. 2020. "U.S Plug-in Electric Vehicle Sales by Month." https://afdc.energy.gov/data/10567; Cooper, A., and M. Shuster. 2019. *Electric Company Smart Meter Deployments: Foundation for a Smart Grid (2019 Update)*. Washington, DC: Institute for Electric Innovation. https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_Smart-Meter-Report_2019_FINAL.ashx.

capacity in September 2019.[52] Wind generated 6.5 percent of the nation's electricity in 2018.

In September 2019, 1.3 million EVs were on U.S. roads, compared to a few hundred in 2010.[53] About 330,000 were sold in 2019.[54] At the end of 2019, there were about 71,000 public and workplace EV charging points.[55]

Smart meters, which enable greater communication between consumers and utilities, were an emerging technology in 2008, but today they are used in nearly 70 percent of U.S. households.[56]

The Growing Affordability of Low-Carbon Technologies

For the longest time, the prevailing narrative about low-carbon technologies was that they could not compete with fossil fuels because of high costs and burdensome subsidies. As recently as January 2014, the *Economist* published an article titled "Why Is Renewable Energy So Expensive?"[57] However, as prices have rapidly declined and low-carbon technologies have come of age, a growing number of these technologies have become increasingly competitive with conventional fossil fuel technologies, even without subsidies. With the right policies, the United States can ensure that this progress applies to more sectors and technologies and that everyone can have equal access.

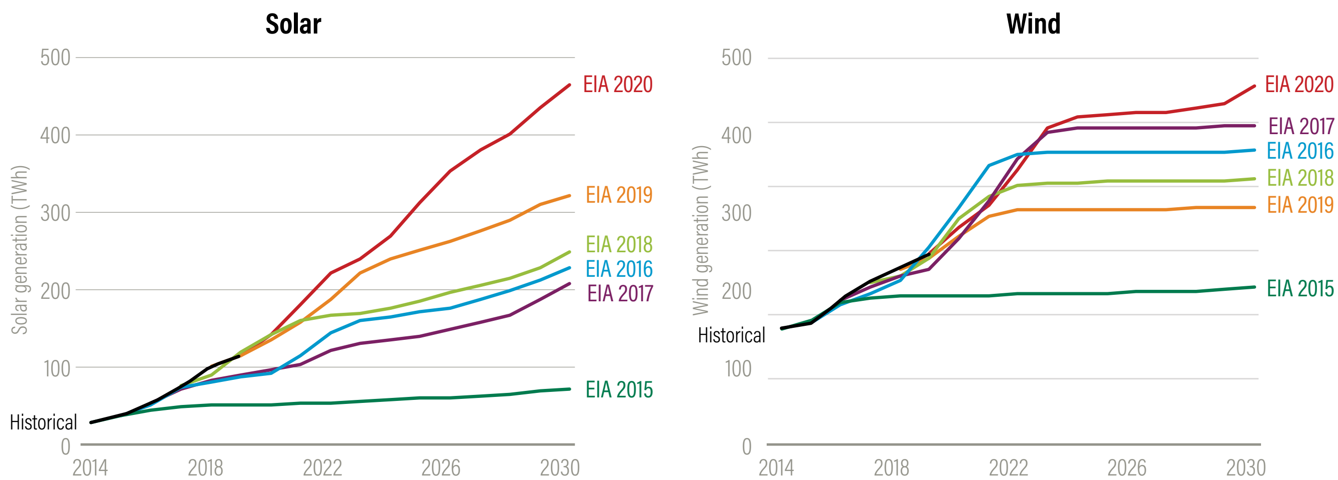
This transformation is most visible in the U.S. power sector. Thanks to technology advances and cost improvements, renewable energy and storage are starting to compete with fossil fuel generation in providing dispatchable power that can be delivered whenever the grid needs it, in many areas of the country without subsidy or valuation of environmental attributes (Figure 6). Around 211 GW of existing coal capacity, or 74 percent of the U.S. coal fleet, is now more expensive to operate than it would be to build and operate new solar and wind energy.[58] By 2025, this will be true for nearly the entire U.S. coal system.[59] New research is also pointing to the fact that clean energy is reaching a tipping point compared to gas. It is now cheaper, in many locations in the United States, to build and use a combination of wind, solar, batteries, and energy efficiency technologies than to build new gas plants.[60] By the middle of the 2030s, continuing price declines and enabling policies could further make it cheaper to build and run new clean energy portfolios than to keep existing gas plants running.[61]

These cost reductions are forcing utilities across the country to rethink their portfolios. For example, PacifiCorp has proposed a plan to retire four coal units in Wyoming and replace them with a portfolio of wind, solar, and storage technologies, a move it says will save customers $248 million over the next 20 years.[62] Florida Power & Light is proposing to build the nation's largest energy storage project powered by utility-scale solar, which will enable it to retire two gas-fired plants.[63] Proposals to build new gas plants are also drawing increasing scrutiny from state regulators who are worried about stranded gas assets in the face of declining renewable and battery prices. In September

Box 1 | Renewable Energy Is Growing Faster than U.S. Government Scenarios Expected

The reference case scenarios of the U.S. Energy Information Administration (EIA) have often been out of sync with historical experience. Almost every year, the EIA has had to increase its renewable energy scenarios because deployment exceeds its expectations, in part because its model is not set up to recognize changes in policy like clean energy tax credits or substantial advances in technology (see Figure B1.1). The problem with underestimating clean energy growth is that it can convince companies to overinvest in fossil fuels, which may become stranded assets as they later struggle to compete with cheaper clean energy. As recently as 2019, the EIA had forecasted that natural gas would remain the leading source of electricity generation until 2050. This year, the EIA forecasts renewables to overtake natural gas after 2045 in overall generation. Still, in the EIA's 2020 outlook, it assumes that annual growth rates for solar and wind energy generation over the next decade will only be about half as fast as they have been over the past five years.

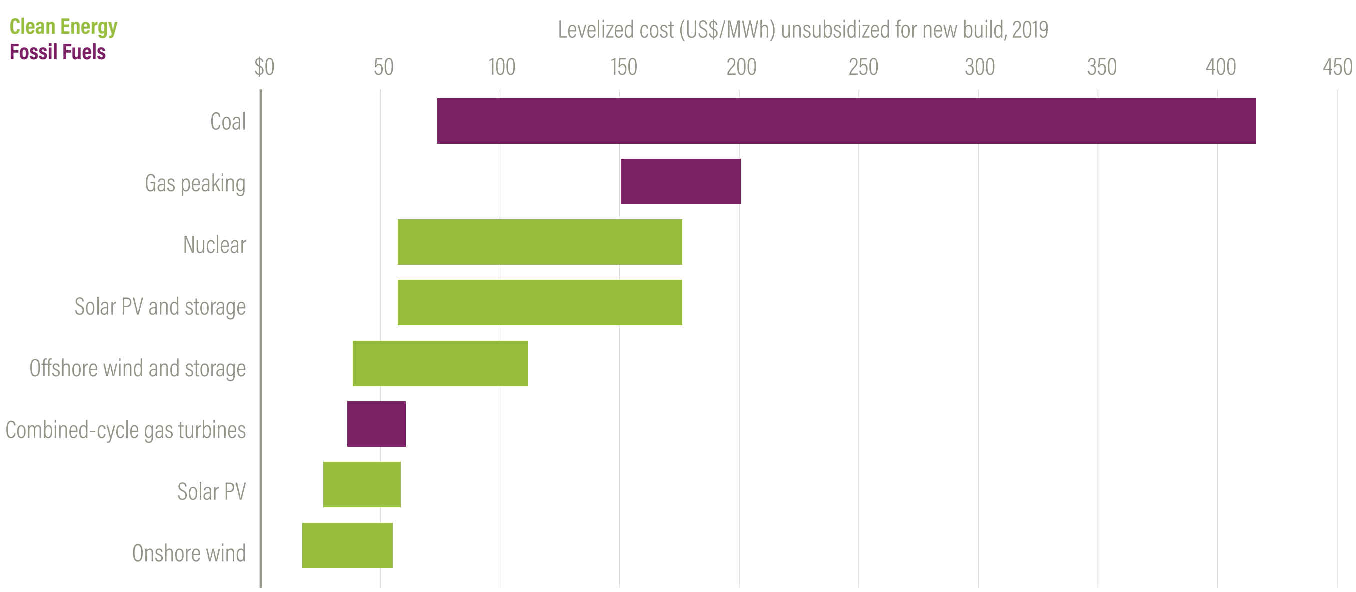
FIGURE B1-1 | EIA ANNUAL ENERGY OUTLOOK ENERGY GENERATION PROJECTIONS OVER TIME



Notes: EIA = U.S. Energy Information Administration; TWh = terawatt-hour.

Source: Authors' analysis based on the U.S. Energy Information Administration's *Annual Energy Outlook* reports for 2015–20. https://www.eia.gov/outlooks/aeo/.

Figure 6 | Renewable Energy Is Reaching Cost Parity with Fossil Fuels



Notes: MWh = megawatt-hour; PV = photovoltaic.

Sources: Lazard. 2019. "Levelized Cost of Energy and Levelized Cost of Storage 2019." November 7. https://www.lazard.com/perspective/lcoe2019; BloombergNEF and Business Council for Sustainable Energy. 2020. *2020 Sustainable Energy in America Factbook*. New York: BloombergNEF; Washington, DC: Business Council for Sustainable Energy. www.bcse.org/factbook/#.

2019, Minnesota regulators rejected a proposal from Xcel Energy to purchase a 720 MW gas plant over concerns the deal is not in the interest of ratepayers.[64] Xcel will still buy the plant and run it as a "merchant plant" that ensures the cost of the facility is not incorporated into regulated rates.

The transportation sector is also changing as prices decline for EVs, though affordability is still an issue for many consumers. EVs are already much cheaper to operate and maintain than internal combustion engine (ICE) vehicles; even with gasoline prices at a low $1.85[65] due to declining demand from the COVID-19 crisis, the cost of the equivalent amount of electricity for an EV is still lower at $1.15.[66] Many analysts are forecasting EV purchase price parity with ICE vehicles in the coming decade, which will be a tipping point for a rapid switch from gas guzzlers to EVs. According to one estimate, EV cost parity with conventional vehicles is likely to occur between 2024 and 2025 for shorter-range and 2026 and 2028 for longer-range EVs in the United States.[67] The arrival of the $33,000 Kia Soul, $36,600 Chevrolet Bolt, and $35,000 Tesla Model 3 already have pushed the price of some EVs below the median price for new cars in the United States.[68]

Fleet owners who operate medium- and heavy-duty vehicles are already responding to the changing economics of EVs. Governments and businesses are highly focused on the total cost of ownership when evaluating vehicle fleet purchases because trucks and vans consume more fuel than smaller vehicles. Fuel costs have accounted for between 21 percent and 39 percent of the total cost of operating a commercial vehicle over the past decade, accounting for variations in price over time and by geography.[69] The California Air Resources Board passed a rule requiring public transit agencies to move to zero-emissions buses by 2040, and cities from Columbus, Ohio, to Washington, DC, have launched their own programs.[70] Under current pledges by states, cities, and urban transit agencies, at least one-third of the nation's nearly 70,000 public transit buses will be all electric by 2045.[71] In September 2019, Amazon announced the largest purchase ever of EVs by a business: 100,000 electric trucks from Michigan-based start-up Rivian, which is part of its effort to eliminate its carbon footprint by 2040.[72] Amazon's announcement is part of an industry-wide trend. FedEx and UPS, which currently have relatively smaller fleets of EVs, are developing bold long-term electrification plans for their delivery vehicles.[73] With electric trucks—including both medium-duty delivery trucks and long-haul intercity tractor trailers—likely to reach cost parity with diesel during the 2025–30 time frame, the adoption of EV technology in the freight sector will only gather more speed.[74]

For new buildings, "going green" is cost effective.[75] Over the lifetime of a green building, the lower energy and operating costs and increased market value outweigh the higher up-front costs. However, the transition to sustainable buildings is not proceeding as fast as it should because developers often overestimate the costs of green buildings, and occupants pay little attention to the effects of energy efficiency on their electricity bill.[76] New policies will be needed, and the cost effectiveness of new technologies will need to be communicated to building owners and occupants to increase demand. In buildings and appliances, energy efficiency has reduced emissions and saved consumers money (Box 2).

Similarly, heating and cooling buildings with electricity can improve both cost and carbon savings. Although the up-front costs for an electric heat pump are higher than for a natural gas furnace, they can be cheaper over the equipment's lifetime. Current estimates from four cities with a range of climates show that the electrification of residential space and water heating saves between $1,000 and $10,000 in lifetime costs for both new construction and retrofitted homes.[77] Other studies on the cost effectiveness of retrofitting existing residential buildings with heat pumps have found that they are most competitive when replacing both a heating system and an air conditioner, replacing technologies that rely on more expensive fuels (homes using oil and propane), or where electricity prices are low.[78,79] In contrast, new construction can be designed to be all electric and works out to be cheaper for homeowners due to savings in installation and maintenance costs, including the avoided costs of new gas line extensions.[80]

The coming years will witness continued improvements and cost reductions to current emissions-reducing technologies. However, policies, regulations, and incentives will be vitally important to increase consumer adoption of these technologies, especially in the early stages of a transition. The penetration of these technologies should also be accompanied by policies that put equity front and center. Low- and middle-income consumers and disadvantaged communities should have ample opportunity to reap the benefits of these technologies.

Box 2 | Energy Efficiency

Were it not for energy efficiency, the United States would be using far more energy than it does today. It would have taken 300 additional large power plants to meet the demand that has been reduced because of energy efficiency since 1990.[a] Instead of building more energy resources, it is cheaper and more climate friendly to reduce demand with energy efficiency. Saving one unit of energy with utility energy efficiency programs costs about one-quarter to one-half as much as building new resources to provide that same unit of energy.[b] Energy efficiency is also the largest source of clean energy jobs in the United States.

The first federal appliance efficiency standards were established in 1987 by Congress and have been strengthened multiple times since then.[c] The standards have encouraged innovation, and energy efficiency, appliance quality, and consumer welfare have increased while prices have declined.[d] Today, refrigerators use only one-quarter of the energy they did in 1973, even though they cost half as much and have more storage capacity. It is a similar story for other appliances, including washing machines, dishwashers, air conditioners, and furnaces.[e] The average American family saved nearly $500 on utility bills in 2015 due to federal efficiency standards for appliances, lighting, and plumbing products. Consumer benefits from national efficiency standards outweigh the costs by at least five to one.[f] States can also adopt their own appliance standards for products not covered by federal standards. If states adopted strong efficiency standards for products such as computers and faucets, the average household could save $72–$215 annually by 2035, depending on the state.[g]

Likewise, fuel economy standards have helped Americans save money at the pump. The lower fuel costs more than offset the added technology costs to make vehicles more efficient. From 2008 to 2016, federal fuel efficiency standards for light-duty vehicles had a benefit-to-cost ratio of more than five to one, including consumer pocketbook savings, macroeconomic benefits, and environmental benefits. Fuel efficiency is particularly beneficial for low-income Americans, who spend more on gasoline as a percentage of household income and are more likely to buy used vehicles.[h,i] The price of both new and used vehicles has remained flat over the past two decades while fuel economy for both has continually improved.[j]

A large expansion of energy efficiency efforts across all sectors of the economy combined with electrification could cut U.S. energy use 49 percent and greenhouse gas emissions 57 percent by 2050.[k] Of the emissions reductions, nearly half would come from energy efficiency in transportation, a third from buildings, and a fifth from industry. The energy saved from these policies would be worth $704 billion, and energy productivity would more than triple.[l]

a, b. Molina, M., P. Kiker, and S. Nowak. 2016. *The Greatest Energy Story You Haven't Heard: How Investing in Energy Efficiency Changed the US Power Sector and Gave Us a Tool to Tackle Climate Change.* Washington, DC: American Council for an Energy-Efficient Economy. http://www.ourenergypolicy.org/wp-content/uploads/2016/08/The-Greatest-Energy-Story.pdf.

c. Stickles, B., J. Mauer, J. Barrett, and A. deLaski. 2018. *Jobs Created by Appliance Standards*. Report A1802. Washington, DC: American Council for an Energy-Efficient Economy and Appliance Standards Awareness Project. https://aceee.org/sites/default/files/publications/researchreports/a1802.pdf.

d. Brucal, A., and M. Roberts. 2019. "Do Energy Efficiency Standards Hurt Consumers? Evidence from Household Appliance Sales." *Journal of Environmental Economics and Management* 96 (July): 88–107. https://doi.org/10.1016/j.jeem.2019.04.005.

e. U.S. Department of Energy. 2017. "Saving Energy and Money with Appliance and Equipment Standards in the United States." Washington, DC: U.S. Department of Energy. www.energy.gov/sites/prod/files/2017/01/f34/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-011917_0.pdf.

f. deLaski, A., and J. Mauer. 2017. "Energy-Saving States of America: How Every State Benefits from National Appliance Standards." White Paper. Washington, DC: Appliance Standards Awareness Project and American Council for an Energy-Efficient Economy. https://appliance-standards.org/sites/default/files/Appliances%20standards%20white%20paper%202%202-14-17.pdf.

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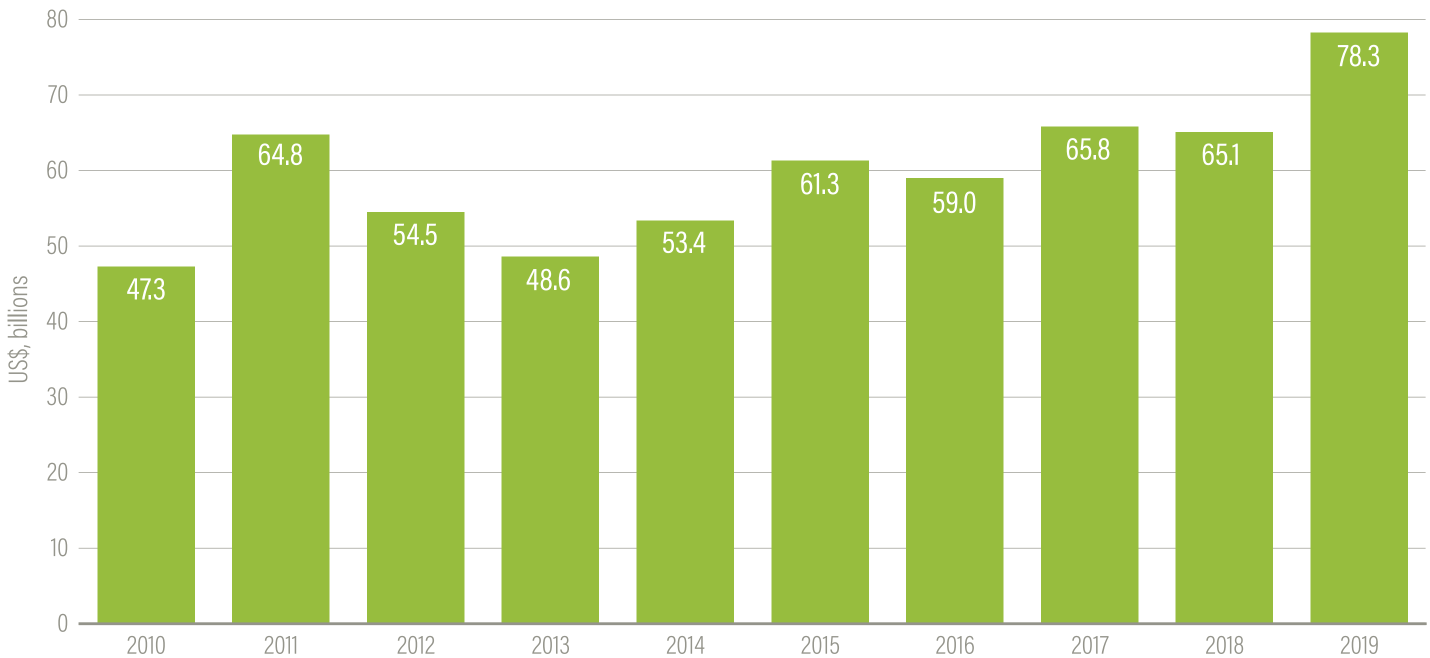
i. Union of Concerned Scientists. 2017. "Fuel Efficiency, Consumers, and Income." Cambridge, MA: Union of Concerned Scientists. www.ucsusa.org/sites/default/files/images/reports/vehicles/cv-factsheet-fuel-economy-income.pdf.

j. Comings, T., and A. Allison. 2017. "More Mileage for Your Money: Fuel Economy Increases While Vehicle Prices Remain Stable." Cambridge, MA: Synapse Energy Economics, Prepared for Consumers Union. https://advocacy.consumerreports.org/wp-content/uploads/2017/03/Synapse-CU-Affordability-Report-3-15-corrected-1.pdf.

k, l. Nadel, S., and L. Ungar. 2019. *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050*. Washington, DC: American Council for an Energy-Efficient Economy. https://aceee.org/research-report/u1907.

Figure 7 | **U.S. Clean Energy Investment, 2010–19**



Source: BloombergNEF. 2020. Clean Energy Investment Trends, 2019. New York: BloombergNEF. https://data.bloomberglp.com/professional/sites/24/BloombergNEF-Clean-Energy-Investment-Trends-2019.pdf.

Growing Investment and the Greening of the Financial Sector

By mobilizing capital at the required scale and pace, the financial sector is a critical enabler of the shift to a new climate economy. The U.S. and global response to climate change will involve a massive shift of financial resources from carbon-intensive production and consumption to less-polluting, low-carbon alternatives. This shift has already begun. Banks and investors are increasingly using climate finance instruments like green bonds, engaging in public-private partnerships, and divesting from fossil fuels. However, the need to accelerate investment in low-carbon technologies remains more urgent than ever before because economic uncertainties caused by the COVID-19 pandemic and falling oil prices have upended global financial markets and have heightened financial volatility.

In response to a rapid decline in the cost and technology risk of low-carbon technologies, investment in low-carbon solutions is growing in the United States. Led by investments in wind and solar, U.S. clean energy investment rose 20 percent to $78.3 billion in 2019.[81] This was a new record, surpassing the previous high of $65.8 billion in 2017 (Figure 7).

U.S. investment in renewable energy, however, has been influenced heavily by the schedule for the expiration of the production tax credit (PTC) for wind and the investment tax credit (ITC) for solar. Currently, wind projects can qualify for the PTC through 2020, and the ITC for solar will phase down to a permanent 10 percent in 2022. Under normal circumstances, the phasing out and/or phasing down of these tax credits could have had a muted impact, with competitive economics driving growth in wind and solar. However, manufacturing, supply chain, and permitting disruptions caused by the COVID-19 outbreak have put wind and solar projects off track, threatening their ability to qualify for the tax credits. The temporary extension of "safe harbor" deadlines from four to five years will give wind and solar developers more time to meet the requirements of the tax credits, but the phaseout schedule and the nonrefundability of the current tax credits remain barriers to attracting investment in this economic climate.[82]

Globally, the low-carbon economy presents a sizable business opportunity to U.S. companies, with a $23 trillion investment opportunity in emerging markets alone between now and 2030.[83] The extent of America's investment in the low-carbon economy will, therefore, have important implications for its standing in what is shaping up to be the next big global industry.

There are some troubling signs on this front. U.S. low-carbon investment continues to lag behind China, raising questions about whether the United States will lead or follow in the global low-carbon market. China is the top country by far in terms of the amount invested in renewables capacity during the last decade: $758 billion committed between 2010 and the first half of 2019, compared to $356 billion by the United States (Figure 8).[84] A similar story is unfolding in the transportation sector, where automaker investments in electric transportation are mostly falling outside the U.S. market. According to the Atlas Public Policy EV Hub database, the United States is poised to receive only 10 percent of $350 billion in global EV investment announced by automakers as of May 2019, whereas China will receive 40 percent.[85] German and Chinese companies are the leading EV investors, committing to almost $200 billion for transportation electrification. U.S. companies, in contrast, have only committed $34 billion to EV development.

Low-carbon investment in sectors beyond power is growing but needs to scale up to meet the challenges of those sectors. The industrial, heavy-duty transport, and land sectors, including agriculture, have yet to draw significant low-carbon investment. A combination of market risks and incomplete policy support has dampened interest from private investors. In 2018, only 2 percent and 10 percent of global green bond proceeds were earmarked for low-carbon projects in the industrial and land-use sectors, respectively.[86]

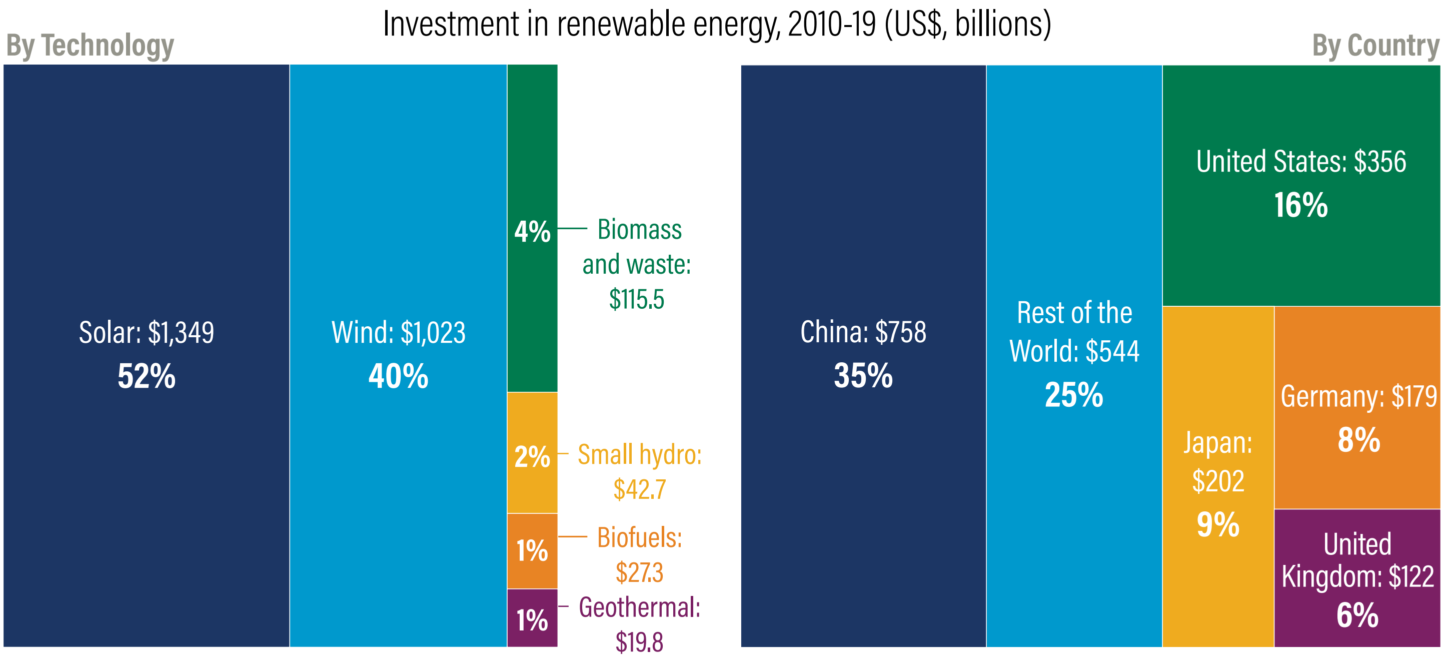
The financial sector will have to play a key role in channeling more investment towards low-carbon activities, but its record to date has been less than satisfactory. Calls are growing for the financial sector to acknowledge and integrate the risks posed by climate change into planning and lending practices and discontinue the financing of carbon-intensive activities. Thirty-three global banks committed $1.9 trillion towards fossil fuel financing between 2016 and 2018, and a number of North American banks were among the leading lenders to fossil fuel projects.[87] The top 40 U.S. insurers hold $450 billion in fossil fuel investment, a higher proportion than average index funds.[88]

Recent developments in the financial sector raise optimism. The financial sector is beginning to recognize the risks associated with climate change and also the opportunities arising from climate action. A growing number of U.S. insurers are divesting from fossil fuel.[89] Big banks, including Goldman Sachs, JPMorgan Chase, and Wells Fargo, are pulling back from financing oil and gas extraction in the Arctic region and coal projects around the world.[90] BlackRock has joined the Climate Action 100+, an investor initiative to get the world's biggest emitters to reduce their emissions. This represents a big boost for climate finance from one of the world's largest investors. At the same time, some of the world's biggest investors, including those managing more than $34 trillion in assets, or nearly half the world's invested capital, now see climate change as an investment priority.[91] In the United States, financial institutions say that, under the right policy conditions, they could double their planned investments in the U.S. renewable energy sector, with the potential to mobilize $1 trillion in cumulative private capital by 2030.[92]

Major corporations are playing a significant role in driving investment in renewable energy and making ambitious commitments to reducing their carbon footprints. More than 200 multinational companies have formally committed to 100 percent renewables through the RE100 initiative. U.S. companies are at the forefront, having purchased 13.6 GW of renewables in 2019, the majority of the world's total corporate procurement.[93,94] Microsoft has committed to become carbon negative by 2030. This means it will remove more CO_2 from the atmosphere than it emits, and by 2050, it will remove all the carbon it has emitted since its creation in 1975.[95] Although the technology sector is driving corporate clean energy purchases, a growing number of oil and gas companies, including Occidental Petroleum, ExxonMobil, Chevron, and Energy Transfer Partners, are also making low-carbon purchases (Figure 9).[96]

The United States needs to ramp up investments in low-carbon technologies at a greater speed and scale. This presents both a tremendous challenge and an enormous opportunity, and it is achievable if investors, businesses, and governments work together to display climate leadership. The economic crisis brought on by the COVID-19 outbreak has only heightened the fact that the United States must create a strong foundation that can enable the American economy to weather the threats and challenges of this century effectively. Doubling down on low-carbon investment cannot only act as a near-term stimulus to reboot the American economy, but over the long-term it also can position the United States to address the threats posed by climate change.

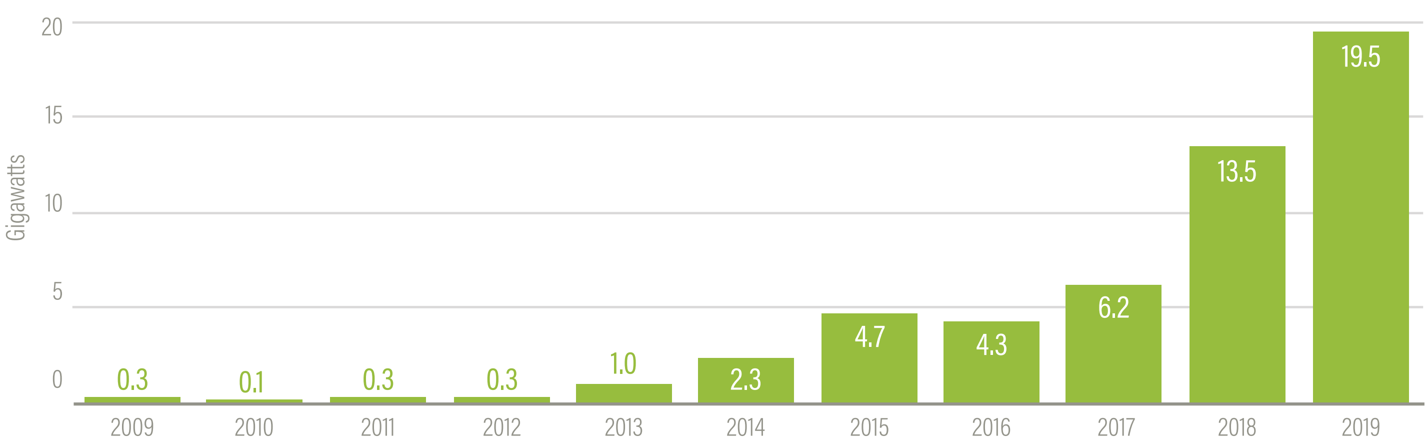
Figure 8 | **Global Investment in Renewable Energy Technologies and Country Share, 2010–19**



Note: Includes investments from 2010 to the first half of 2019.

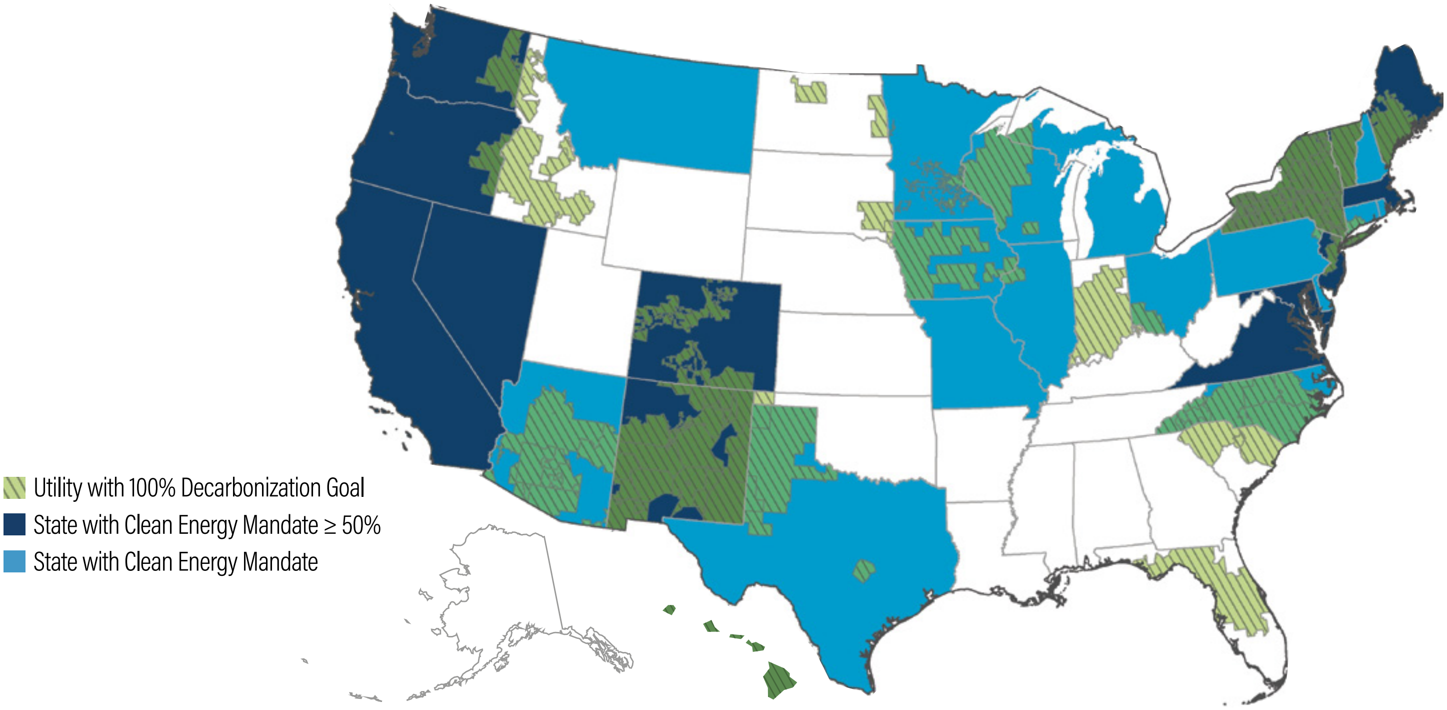
Source: Frankfurt School–United Nations Environment Programme Collaborating Centre for Climate & Sustainable Energy Finance and BloombergNEF. 2019. Global Trends in Renewable Energy Investment. Frankfurt, Germany: Frankfurt School of Finance & Management.

Figure 9 | **Global Corporate Clean Energy Purchases**



Source: Walton, R. 2020. "Fueled by Flexible PPAs, Corporate Clean Energy Purchases Surged to 19.5 GW in 2019: BloombergNEF." Utility Dive, January 29. https://www.utilitydive.com/news/fueled-by-flexible-ppas-corporate-clean-energy-purchases-surged-to-195-gw/571299/.

Figure 10 | **U.S. States with Clean Electricity Mandates and Utilities with Decarbonization Goals, 2019**



Source: WRI and Smart Electric Power Alliance.

State and Local Policy Momentum

Governors and mayors are implementing innovative policies to reduce emissions while stimulating economic development. A growing number of U.S. states, cities, and counties are committed to climate action, even in the absence of federal leadership. This coalition now represents 68 percent of U.S. GDP, 65 percent of U.S. population, and 51 percent of U.S. emissions.[97]

The growing momentum for climate action has given rise to ambitious commitments and an impressive array of new legislation and measures to convert commitments and goals into concrete outcomes. Carbon pricing is being implemented at the subnational level. California has had a suite of climate policies for decades, including an economy-wide cap-and-trade system in place since 2015. Through the Regional Greenhouse Gas Initiative (RGGI), 10 northeastern and mid-Atlantic states are capping power sector emissions, with Virginia and Pennsylvania poised to join.[98]

Renewable energy and energy efficiency policies have become commonplace. Thirty states have renewable portfolio standards that mandate increased production of clean electricity.[99] Twenty-seven states have an energy efficiency resource standard, which requires utilities to meet energy savings targets.[100] In the past few years, there has been a wave of states declaring their commitment to 100 percent clean electricity. Twelve states, plus the District of Columbia and Puerto Rico, have adopted laws or issued executive orders with 100 percent clean electricity targets, with a number of other states taking additional actions to decarbonize their electric grid. In addition, 204 cities and counties across 37 states have committed to 100 percent clean electricity (Figure 10).[101]

Examples from other sectors of the economy show the breadth of action being taken at the subnational level. In transportation, Colorado became the 11th state to commit to a zero-emissions vehicle standard to increase sales of EVs, and Minnesota and New Mexico plan to join.[102] Building on the success of the RGGI, 12 northeastern and mid-Atlantic states and the District of Columbia—composing the Transportation and Climate Initiative—are developing a new regional policy proposal to cap and reduce emissions from the transportation sector. Berkeley, California, became the first U.S. city to ban the use of gas in new low-rise buildings and has sparked a trend for other cities to do likewise. Washington State has established the nation's first state-level energy performance standard for large commercial buildings and provided $75 million in incentives for building retrofits under its landmark 2019 Clean Buildings Act. California's Buy Clean Act, requiring state agencies to weigh the carbon footprint of materials used in infrastructure projects, is a first-of-its-kind regulation aiming to incentivize low-carbon manufacturing and the use of less carbon-intensive construction materials.[103] California, Colorado, Massachusetts, New Mexico, and Pennsylvania are developing regulations to reduce methane emissions and prevent waste from oil and gas infrastructure.[104]

Subnational efforts like the ones mentioned above are helping to lay the groundwork for large-scale climate action. Supportive bottom-up policies by states and cities have made it possible for low-carbon technologies to make inroads into mainstream America. While these policies are laudable, the planet's health cannot rely solely on subnational actions. According to America's Pledge, with the help of bottom-up efforts, the United States is on track to reduce its emissions 25 percent below 2005 levels by 2030.[105] With enhanced bottom-up action, the country could reduce emissions 37 percent by 2030 or, if combined with ambitious federal action, 49 percent by 2030, which would be on track with the goals of the Paris Agreement.[106] A comprehensive effort to address climate change will require the federal government to promote the transition to America's new climate economy rather than sit on the sidelines or actively try to slow it down. In the meantime, U.S. subnational actors can continue their leadership and accelerate the adoption of substantive climate policies.

Despite the significant progress made, this is not a moment for complacency. The United States is not on track to avert the worst impacts of climate change. Significant challenges remain in reducing emissions from hard-to-abate sectors like heavy industry, trucking, aviation, and shipping. The increasing investment in gas infrastructure threatens the clean energy progress the country has made. The COVID-19 pandemic and falling oil prices are also likely to slow down the low-carbon transition in the near term, even as they have highlighted the need to rebuild the American economy in a manner that is better able to absorb future shocks from other types of crises, including climate change.

This decade is crucial for climate action. America must seize and sustain the momentum to ensure that the promise of its new climate economy remains within reach.

3. THE ECONOMIC CASE FOR A NEW CLIMATE ECONOMY

Jobs and Economic Growth

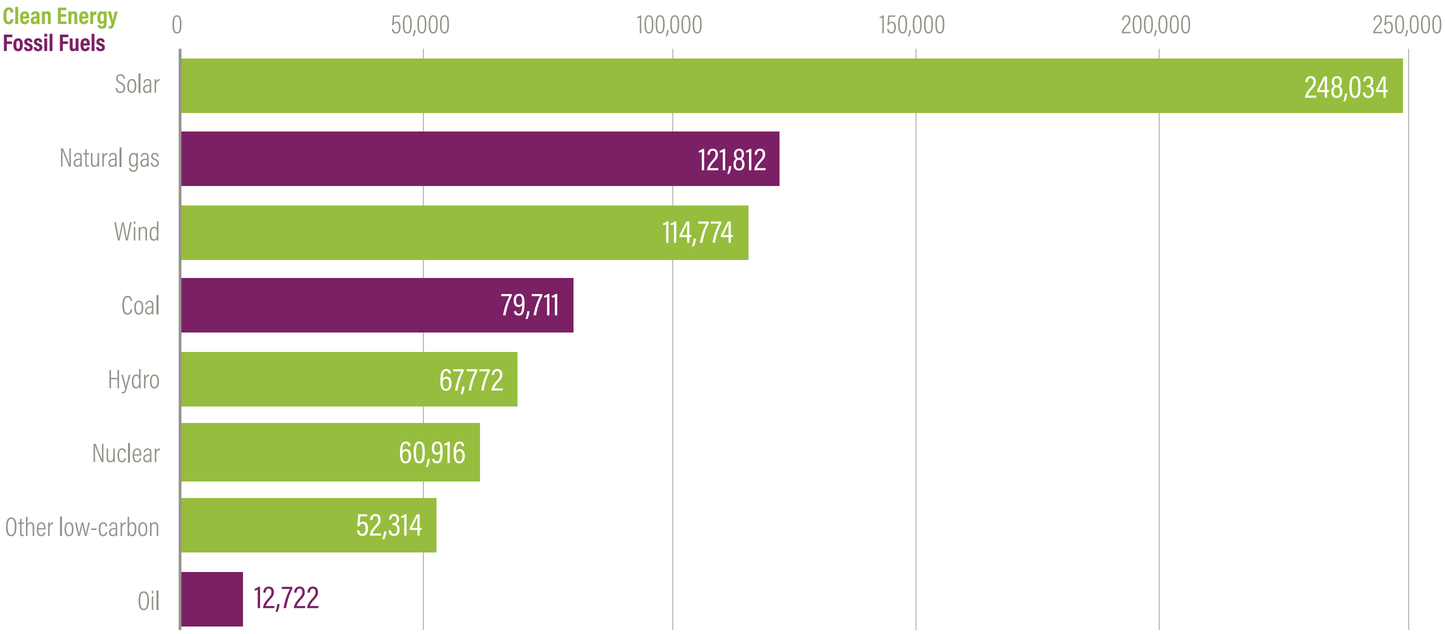
Clean Energy Jobs Today

For years, workers in clean energy industries have been an important, fast-growing part of the U.S. labor force. In 2019, more than 3.6 million Americans had clean energy jobs in energy efficiency, power generation, fuels, and vehicles, according to the *2020 U.S. Energy and Employment Report*.[107] That is more than all workers in grocery and liquor stores across the country.[108]

The growth in clean energy jobs had been projected to continue in 2020; however, the economic fallout from the COVID-19 pandemic has dried up investment across the economy, including for clean energy. In March and April, one study estimated that almost 600,000 clean energy workers lost their jobs as a result of the COVID-19 crisis, at a rate just slightly higher than the nation as a whole.[109] The ability of these sectors to rebound after the crisis passes will depend on how effectively countries can address supply chain interruptions as well as the steps the United States takes to encourage continued investment. There are initial signs that the renewable energy industry is weathering the crisis better than fossil fuels. The oil industry is in a difficult position because there is an oversupply coupled with low demand that is not expected to rebound to pre-COVID levels. Low prices have halted the shale boom, with at least 20 North American oil and gas producers going bankrupt this year.[110] Several major oil companies are writing down their assets and on a shift to clean energy. Meanwhile, renewable energy is projected to reach a new high as a percentage of the electricity mix in 2020; renewables are the first choice when electricity demand is low because they are cheaper to operate. While there will be a shock in the short term, clean energy could be in a better position in the future to continue creating jobs.[111]

Looking back to 2019, the largest clean energy sector was energy efficiency, which employed 2.4 million Americans. This number includes people working with Energy Star appliances, advanced and recycled building materials, LED lighting, and renewable heating and cooling. Slightly more than half of these jobs are in construction, but others are in manufacturing, wholesale trade, and professional and business services. More than one in six jobs in the construction sector were in energy efficiency.[112]

Figure 11 | **Renewable Energy Employs More in U.S. Power Generation than Fossil Fuels**



Notes: An additional 97,400 employees spend less than 50 percent of their time on solar. "Other low-carbon" includes bioenergy, combined heat and power, and geothermal power.

Source: National Association of State Energy Officials and Energy Futures Initiative. 2020. The 2020 U.S. Energy and Employment Report. Arlington, VA: National Association of State Energy Officials; Washington, DC: Energy Futures Initiative. https://www.usenergyjobs.org/s/USEER-2020-0517.pdf.

In the power sector, zero-emissions generation like solar and wind was responsible for about 544,000 jobs, more than twice as many as the 214,000 jobs in fossil fuel generation (see Figure 11). In the fuel extraction, mining, and processing sector, there were more than 890,000 oil and gas jobs, though biofuels do support about 108,000 jobs. In total, across power generation and fuels, about 35 percent of jobs were in low-carbon technologies. Battery storage also employed 66,000.

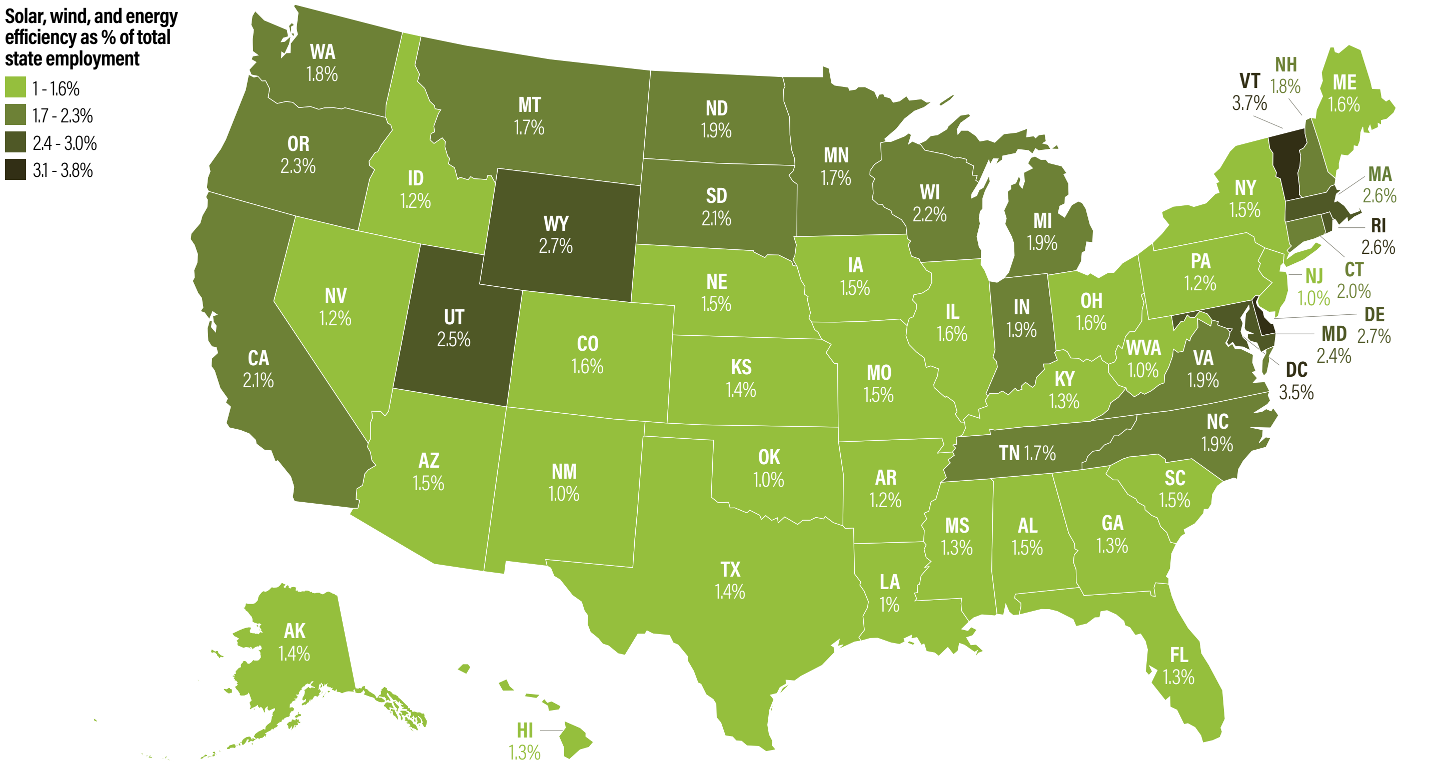
The automobile industry has also been undergoing a transition. Nearly 494,000 Americans worked with products that contribute to vehicle fuel economy in 2019, which was 19 percent of jobs in the motor vehicle sector. A total of 266,000 people worked on electric, hybrid electric, and alternative fuels vehicles, 10 percent of all jobs in the motor vehicle sector (with some overlap with fuel efficiency workers).[113]

One study has indicated that the mean hourly wages for clean energy jobs are higher than the national average by 8–19 percent.[114] They are also accessible to a wide range of workers, including those without a college degree. Labor union leaders representing 12.5 million American workers put out a statement in December 2019 that "addressing climate change is what's best for the economic health, jobs, and competitiveness of our companies and our country."[115]

The quality of clean energy jobs remains an important concern though. A good portion of these jobs are nonunion or contractor based, with less job security and little to no benefits like health care. In some cases, wages are lower than traditional energy jobs. The United States should pay particular attention to job quality, equal access, and upward mobility in the new climate economy (see Section 5).

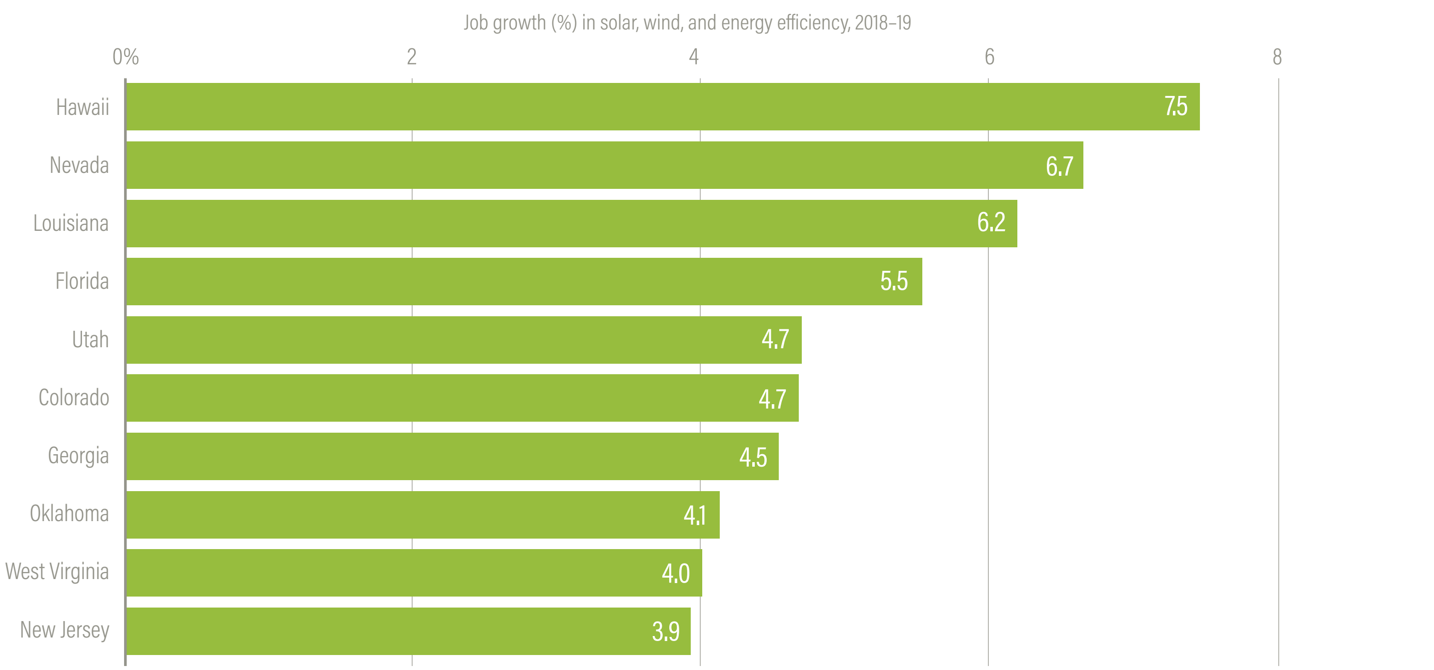
Adjusting for the size of each state, clean energy jobs are well distributed throughout the country, though they are more likely to be located in states with supportive policies and abundant renewable resources, like the sun in the Southwest or the wind in the Midwest (see Figures 12 and 13). Energy efficiency jobs are extremely well distributed since construction jobs can be anywhere. There is currently a lack of data on jobs in other parts of the low-carbon economy besides clean energy, such as jobs in sustainable land use or recycling, but they are also an important part of the American workforce.

Figure 12 | Clean Energy Jobs by State



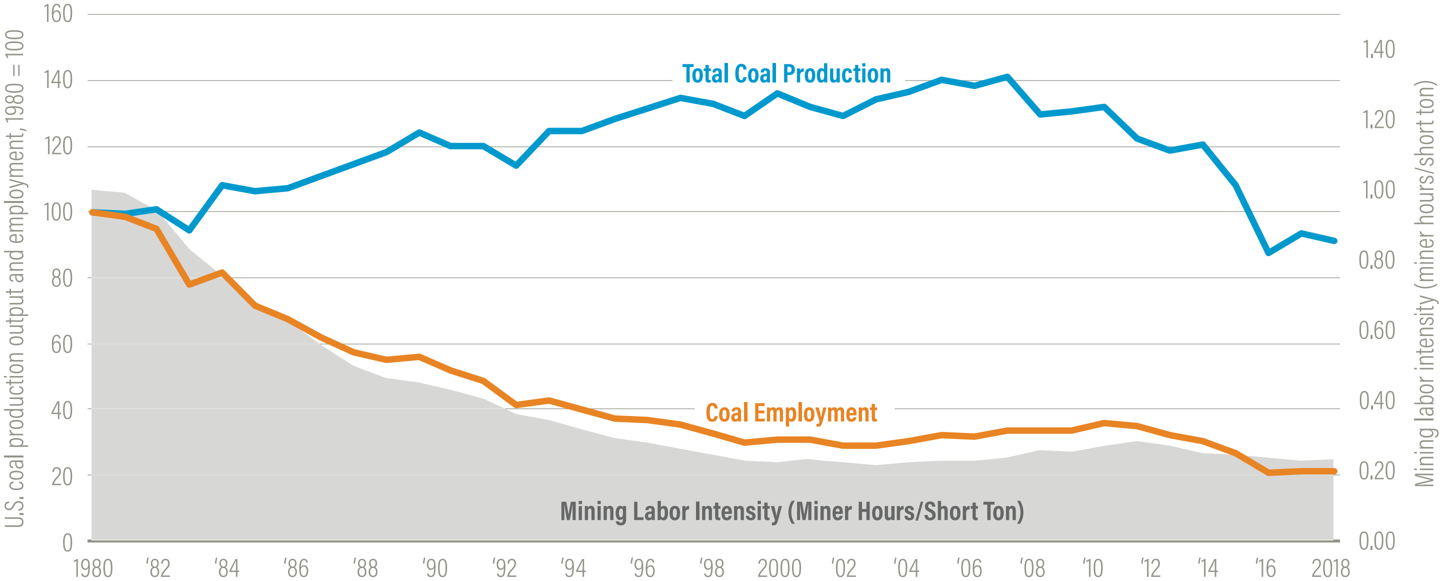
Sources: National Association of State Energy Officials and Energy Futures Initiative. 2020. *The 2020 U.S. Energy and Employment Report*. Arlington, VA: National Association of State Energy Officials; Washington, DC: Energy Futures Initiative. https://www.usenergyjobs.org/s/USEER-2020-0517.pdf; Bureau of Labor Statistics. 2018. "State and Metro Area Employment, Hours, & Earnings." https://www.bls.gov/sae/.

Figure 13 | Top 10 States for Clean Energy Job Growth



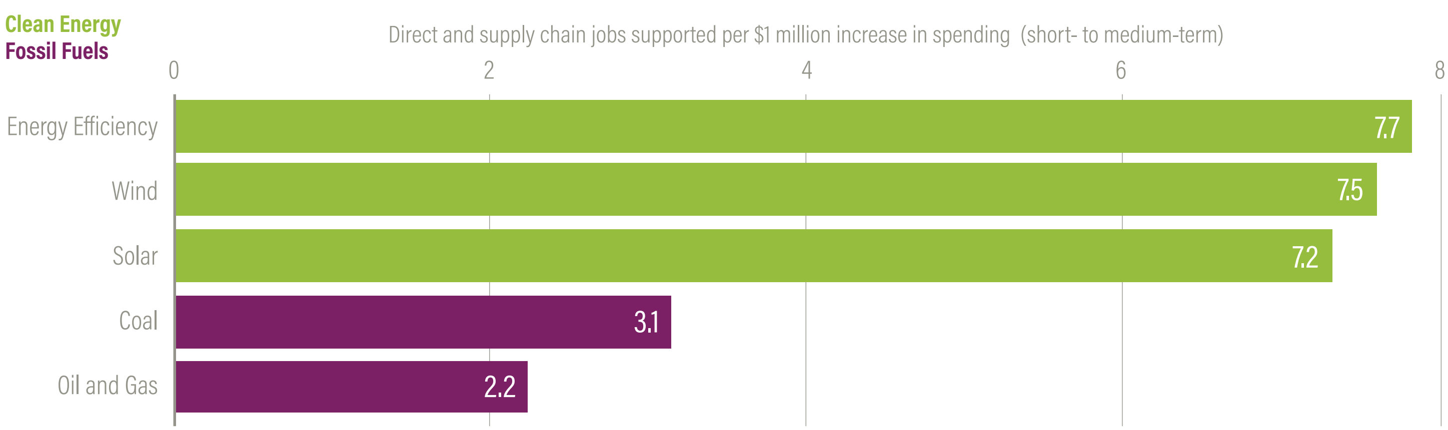
Source: National Association of State Energy Officials and Energy Futures Initiative. 2020. *The 2020 U.S. Energy and Employment Report*. Arlington, VA: National Association of State Energy Officials; Washington, DC: Energy Futures Initiative. https://www.usenergyjobs.org/s/USEER-2020-0517.pdf.

Figure 14 | Due to Automation, Coal Employment Fell Even as Production Increased



Source: Based on WRI's analysis of U.S. Energy Information Administration's annual coal report data and Bureau of Labor Statistic's coal mining employment data.

Figure 15 | Renewable Energy Supports More Jobs than Fossil Fuels per $1 Million of Spending



Source: Garrett-Peltier, H. 2017. "Green versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using an Input-Output Model." *Economic Modelling* 61 (February): 439–47. https://doi.org/10.1016/j.econmod.2016.11.012.

Why Clean Energy Is a Job Creator

The early stages of the COVID-19 pandemic have caused U.S. unemployment numbers to spike. This makes it essential to understand why investing in clean energy and other low-carbon sectors can be an effective way to create more jobs than other options, such as investing in fossil fuel infrastructure.

In the fossil fuel sector, dynamics such as automation and productivity gains are already transforming employment, especially in the coal industry. (see Figure 14).[116] The number of coal workers needed per unit of output has fallen more than fivefold in the past 60 years.[117] This is due to improved productivity and the shift from Eastern coal to heavily mechanized Western coal. In recent years coal jobs have fallen further as coal prices are undercut by the price of natural gas and renewables. It is primarily technology and economics, not environmental regulations, that have caused the decline in coal jobs, and even if there were a return to old levels of coal output it would not be accompanied by a return to the old number of jobs. The extensive use of analytics and automation within new gas-fired power plants is creating a significant employment shift in the gas industry too.[118] A key challenge will be to ensure that these transitions are fair, with policies to smooth the adjustment for affected workers and communities.

Whereas fossil fuels are more capital-intensive, clean energy is generally more labor-intensive, so investing in clean energy can create more new jobs.[119] This will be especially true during the initial build-out of clean energy capacity, which will support manufacturing and construction jobs. A 2017 study found that in the short to medium-term, $1 million spent on fossil fuels in the United States will generate about two to three full-time-equivalent jobs, but $1 million spent on renewable energy or energy efficiency will create about seven to eight jobs (see Figure 15).[120] The study does not consider job quality or benefits (see Section 5 for more discussion on the transition from fossil fuel to clean energy jobs).

The shift to EVs will also have important job implications. When EV owners save money on gas or diesel, they inject those savings in other parts of the economy that are more labor-intensive than the petroleum sector, which stimulates the economy and creates jobs.[121] The National Renewable Energy Laboratory found that, considering all the costs and benefits, increasing plug-in EVs to 27 percent of the U.S. fleet by 2035 would generate approximately 52,000 additional net jobs per year and increase GDP $6.6 billion per year on average from 2015 to 2040, compared to a baseline scenario.[122] Although the net employment effects will be positive across the economy, jobs will likely decrease in the auto industry itself. Building and maintaining EVs takes less labor than with gasoline or diesel vehicles because they have simpler power trains and fewer component parts.[123] In addition to EVs, a shift to more autonomous vehicles and shared rides could decrease the number of cars needed.

Energy efficiency is also a job creator. It has been estimated that over 500,000 new full-time jobs could be sustained for a decade by retrofitting about 40 percent of the country's residential and commercial building stock. The retrofits would also generate over $60 billion per year in cost savings for U.S. energy consumers, which would support other much-needed local economic activity.[124] When efficiency policies are implemented, they cause spending to shift from energy utilities, which have a lower labor intensity than the rest of the economy, to other sectors that have a higher labor intensity, including the manufacturing of energy efficient products and the retrofitting of buildings. In addition, when consumers save money on their electricity bills, they spend that money elsewhere in the economy, including on retail, health care, and manufacturing, which are all more labor-intensive than energy.[125] In a traditional regulatory model, utilities would lose money because of this dynamic; however, many states have developed regulations that decouple utility revenues from electricity sales and instead incentivize utilities to pursue energy efficiency.

Research finds that investments in transit, pedestrian, and cycling projects have a bigger employment impact than investments in roads. Stimulus spending from the 2009 American Recovery and Reinvestment Act offers a good test case because states spent money on transportation in different ways. Most of the money was spent on road projects, but states like Georgia, Massachusetts, and Oregon spent a substantial amount on public transportation. Of this stimulus money, $1 billion spent on public transit projects created 4.2 million job hours, whereas $1 billion spent on highways created 2.4 million job hours.[126] Walking and cycling projects are also job creators. A study looking at 11 American cities found that investments in cycling projects created 50 percent more jobs as compared to road projects.[127]

In a time like today, when the country is not at full employment due to the COVID-19 pandemic, the fact that clean energy can create so many jobs is a clear benefit (see

Box 3 | Rebuild Better after COVID-19

The World Resources Institute has identified five areas where low-carbon, resilient investments can create jobs and rebuild the U.S. economy after the COVID-19 crisis. These are opportunities that can have an immediate impact while setting the country up for a resilient future.

1. Improve the energy efficiency of residential and commercial buildings. The 2009 American Recovery and Reinvestment Act increased funding for the Weatherization Assistance Program, which supported 28,000 jobs in 2010 alone and raised economic output by $4 billion, and for the State Energy Program, which supported 135,000 job years and saved buildings $7.8 billion in energy costs.[a]

2. Modernize transmission infrastructure. Modeling results show that every $1 billion of U.S. transmission investment can generate 13,000 full-time-equivalent years of employment, and every $1 invested creates $2.40 in economic benefits.[b]

3. Invest in zero-emissions public transportation. Every $1 billion invested in public transportation creates nearly 50,000 jobs and returns $5 billion in economic activity.[c]

4. Boost reforestation and tree restoration. An annual federal investment of $4–$4.5 billion could create more than 150,000 jobs and $6-$12 billion per year in economic activity.[d]

5. Ramp up manufacturing of electric school and transit buses. Replacing 10 percent of the national fleet of diesel buses with electric buses could create manufacturing jobs across the country. New electric buses can achieve the equivalent of 25 miles per gallon, compared to 5 miles per gallon for a diesel hybrid bus, which reduces fuel costs by two-thirds.[e]

a. Carlock, G. 2020. "Building Energy Efficiency and Energy Assistance: Creating Jobs and Providing Relief to States across the Country." WRI COVID-19 Response Special Expert Note Series. Washington, DC: World Resources Institute. https://files.wri.org/s3fs-public/expert-note-building-efficiency-energy-assistance.pdf.

b. Saha, D. 2020. "Grid Modernization: Creating Jobs, Cutting Electric Bills, and Improving Resiliency." WRI COVID-19 Response Special Expert Note Series. Washington, DC: World Resources Institute. https://files.wri.org/s3fs-public/expert-note-grid-modernization.pdf.

c. Carlock 2020.

d. Rudee, A. 2020. "Restoring Trees to the Landscape: Creating 'Shovel-Ready' Jobs across the United States." WRI COVID-19 Response Special Expert Note Series. Washington, DC: World Resources Institute. https://files.wri.org/s3fs-public/expert-note-tree-restoration.pdf.

e. Lashof, D. 2020. "Manufacturing Electric School and Transit Buses: Creating Jobs and Economic Growth." WRI COVID-19 Response Special Expert Note Series. Washington, DC: World Resources Institute. https://files.wri.org/s3fs-public/expert-note-electric-buses.pdf.

Box 3). However, in the longer term, economists treat jobs as a cost because the labor may have been shifted away from other productive uses.[128] For example, rooftop solar costs more than utility-scale solar, even though the panels are the same, because the labor costs of installing the panels are higher. Over time, it should also be expected that automation will make clean energy technologies less labor-intensive, as it did for fossil fuels, and continue to decrease costs. For example, researchers are testing the use of drones for wind turbine inspections, which could be cheaper and less dangerous than having technicians scale turbines.[129]

Ultimately, the transition to clean energy will create more employment opportunities than it removes. And especially when unemployment is high, it can make good use of slack resources while creating jobs. However, whether the economy relies on fossil fuels or renewable energy sources is not the only factor affecting job dynamics. Automation and trade have a bigger effect on worker dislocation than climate policies. Fair and equitable transition policies are important, regardless of the underlying cause of dislocations (see Section 5).

The Economic Impact of Current Climate Policies

While the United States does not have a comprehensive climate change policy, such as a nationwide price on carbon, it has an array of measures, including automobile fuel economy standards, clean electricity standards, tax incentives for clean electricity generation, and building energy codes. Many of the most exciting policies are in place at the state level, as described in Chapter 2, Section 5. A literature review of the economic impact of these state and federal policies reveals that they are reducing emissions while benefiting the economy (see Tables 1 and 2).

However, the Trump administration is dismantling many of the existing climate policies, which will limit their economic benefits in the future. It has already repealed the Clean Power Plan from the U.S. Environmental Protection Agency (EPA), which would have provided

Table 1 | **The Economic Impact of Existing Climate Policies—States**

POLICY	SOCIOECONOMIC EFFECTS
Regional Greenhouse Gas Initiative (RGGI)	A net present value of economic activity of US$1.4 billion and a net increase of 14,500 job years in the most recent analysis period of 2015–17, with similar gains in earlier periods.[a] The public health savings from air quality improvements have been estimated to be worth US$5.7 billion in the 10 RGGI states.[b]
California's cap-and-trade system	Since the cap-and-trade system was rolled out in 2013, California's gross domestic product (GDP) has grown 6.5 percent per year on average, whereas the national GDP has grown 4.5 percent per year.[c] Though this effect is not attributable to the cap-and-trade system, it does show that carbon pricing is compatible with strong growth. The revenue that was invested in climate-friendly projects has had health and greenhouse gas benefits that outweigh the costs by five to one.[d]
Renewable portfolio standards (RPSs)	Existing state RPS policies as of July 2016 are projected to provide $97 billion in domestic air pollution and health benefits and $161 billion in global climate benefits during 2015–50. By reducing the demand for natural gas, consumers are projected to save $78 billion. The effect of compliance on the electric system ranges from a $31 billion cost to a $31 billion benefit, with a maximum increase in electricity prices of one cent per kilowatt-hour; in some sensitivity cases, prices decrease.[e]
Energy efficiency resource standards (EERSs)	State efficiency programs can save customers $2–$5 for every $1 invested.[f] The EmPOWER Maryland EERS generated more than $4 billion in savings for consumers in its first phase from 2008 to 2015,[g] and its recent upgrade to a 2 percent yearly savings requirement has been projected to raise state GDP by $3.75 billion and create 68,000 additional jobs from the implementation of measures during 2017–26.[h]
State zero-emissions vehicle standards	Colorado is one of the most recent states to join the zero-emissions vehicle standard. The economic and pollution benefits are expected to save its residents up to $65 million annually by 2025 and up to $2.2 billion annually by 2040.[i]
Building energy codes	The energy savings from new building energy codes put in place between 2010 and 2016 saved American consumers $2 billion in 2016. This is on top of billions in savings from the implementation of energy codes in previous decades. Continuing modest increases in building energy codes would save consumers $126 billion from 2010 to 2040.[j]

a. Hibbard, P., S. Tierney, P. Darling, and S. Cullinan. 2018. *The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeastern and Mid-Atlantic States*. Boston: Analysis Group. https://www.analysisgroup.com/globalassets/uploadedfiles/content/insights/publishing/analysis_group_rggi_report_april_2018.pdf.

b. Hibbard, P., S. Tierney, P. Darling, and S. Cullinan. 2018. *The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeastern and Mid-Atlantic States.* Boston: Analysis Group. https://www.analysisgroup.com/globalassets/uploadedfiles/content/insights/publishing/analysis_group_rggi_report_april_2018.pdf; Manion, M., C. Zarakas, S. Wnuck, J. Haskell, A. Belova, D. Cooley, J. Dorn, M. Hoer, and L. Mayo. 2017. *Analysis of the Public Health Impacts of the Regional Greenhouse Gas Initiative*. Cambridge, MA: Abt Associates. https://www.abtassociates.com/sites/default/files/2018-06/Analysis%20of%20the%20public%20health%20impacts%20of%20regional%20greenhouse%20gas.pdf.

c. Bureau of Economic Analysis. n.d. "Regional Data: GDP and Personal Income." https://apps.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=1&isuri=1. Accessed December 18, 2019.

d. Breslow, M., and R. Wincele. 2020. *Cap-and-Trade in California: Health and Climate Benefits Greatly Outweigh Costs.* Boston: Climate Xchange. https://1akqm23qb5w51pwn3n2deo7u-wpengine.netdna-ssl.com/wp-content/uploads/2018/08/California_Cap_and_Trade-3-13-2020-spreads.pdf.

e. Mai, T., R. Wiser, G. Barbose, L. Bird, J. Heeter, D. Keyser, V. Krishnan, J. Macknick, and D. Millstein. 2016. *A Prospective Analysis of the Costs, Benefits, and Impacts of U.S. Renewable Portfolio Standards.* Berkeley, CA: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy17osti/67455.pdf.

f. Igusky, K., R. Gasper, M. Obeiter, S. Forbes, N. Aden, and N. Bianco. 2014. "Seeing Is Believing: Creating a New Climate Economy in the United States." Working Paper. Washington, DC: World Resources Institute. https://files.wri.org/s3fs-public/seeingisbelieving_working_paper.pdf.

g, h. Baatz, B., and J. Barrett. 2017. *Maryland Benefits: Examining the Results of EmPOWER Maryland through 2015.* Washington, DC: American Council for an Energy-Efficient Economy.

i. Rykowski, R. 2019. *Colorado Zero Emission Vehicle Program Will Deliver Extensive Economic, Health and Environmental Benefits.* New York: Environmental Defense Fund. http://blogs.edf.org/climate411/files/2019/08/FINAL-EDF-Colorado-ZEV-report-2019.pdf.

j. Athalye, R.A., D. Sivaraman, D.B. Elliott, B. Liu, and R. Bartlett. 2016. *Impacts of Model Building Energy Codes.* Richland, WA: Pacific Northwest National Laboratory.

climate and health benefits worth $55–$93 billion, compared to compliance costs totaling only $8.8 billion.[130] The U.S. Department of Energy (DOE) has proposed rule changes to make it more difficult to set new energy efficiency standards, and it has rolled back new light bulb standards that were set to go into effect in 2020, which were projected to save an average of $100 per household per year by 2025.[131,132,133] The EPA's rule to reduce methane emissions from oil and gas operations also is in danger of rollback, and a similar rule at the Bureau of Land Management (BLM) that applies to public and tribal lands has already been repealed. The BLM rule was estimated to provide $46–$204 million in net benefits per year.[134]

The Trump administration has also proposed weakening federal fuel efficiency standards, which were supposed to reach about 55 miles per gallon in 2025, to only 40 miles per gallon, a level that automakers say they would be on track to reach without regulations.[135] This would cost consumers $231 billion on fuel between 2021 and 2035 compared to the old standards.[136] The rule is expected to be challenged in court. California reached agreement with Ford, Volkswagen, Honda, and BMW to support automobile standards similar to the original standards for 2025, but with the deadline extended by one year; however, the Trump administration has moved to revoke the state's ability to set its own standards.[137] Fuel efficiency standards are beneficial because although customers spend slightly more when purchasing their vehicle, they save much more on gasoline costs over the vehicle's lifetime, and they spend those savings on other productive parts of the economy.

The Economic Impacts of Deep Decarbonization

New, ambitious U.S. policies are needed to reduce GHG emissions enough for the United States to do its part in limiting global warming to safe levels. Fortunately, strong

Table 2 | **The Economic Impact of Existing Climate Policies—Federal**

POLICY	SOCIOECONOMIC EFFECTS
Solar and wind tax credits	The extension of the solar and wind tax credits in 2015 will drive a net increase of more than 80,000 jobs and US$11 billion in economic output on average each year from 2016 to 2025 above a reference scenario with no tax credit extension. U.S. households are projected to realize net electricity bill savings (2012$).[a]
Appliance efficiency standards	Existing appliance energy standards were responsible for about 300,000 net jobs and $58 billion in net economic savings in 2016, which is projected to rise to 547,000 net jobs and $134 billion in net economic savings in 2025 (2017$).[b]
Fuel economy and greenhouse gas standards for vehicles	From 2008 to 2016, light-duty vehicle fuel standards provided consumer pocketbook savings of $209 billion; macroeconomic benefits of $138 billion; and environmental, public health, and other benefits of $47 billion, compared to technology costs of only $71 billion. The overall benefit-to-cost ratio is more than five to one.[c] Medium- and heavy-duty truck standards have also provided net program benefits.[d]
Methane standards for oil and gas	The U.S. Environmental Protection Agency's methane rule is estimated to provide $160 million in net benefits in 2025, with climate benefits outweighing compliance costs.[e]

a. Steinberger, K. 2017. *Engine of Growth: The Extensions of Renewable Energy Tax Credits Will Power Huge Gains in the Clean Energy Economy*. New York: Natural Resources Defense Council. https://www.nrdc.org/sites/default/files/engine-growth-renewable-energy-tax-credits-report.pdf.

b. Stickles, B., J. Mauer, J. Barrett, and A. deLaski. 2018. *Jobs Created by Appliance Standards*. Report A1802. Washington, DC: American Council for an Energy-Efficient Economy and Appliance Standards Awareness Project. https://aceee.org/sites/default/files/publications/researchreports/a1802.pdf.

c. Cooper, M. 2017. *Pocketbook Savings, Macroeconomic Growth and Other Public Benefits of Fuel Economy Standards: Benefit-Cost Analysis of Four Decades of Rules Shows They Have Delivered Trillions of Dollars of Economic Value to Consumer and the Nation*. Washington, DC: Consumer Federation of America. https://consumerfed.org/wp-content/uploads/2017/07/benefits-of-fuel-economy-standards.pdf.

d. U.S. Environmental Protection Agency. n.d. "Regulations for Greenhouse Gas Emissions from Commercial Trucks & Buses." https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks. Accessed June 1, 2020.

e. U.S. Environmental Protection Agency. 2016. "EPA Releases First-Ever Standards to Cut Methane Emissions from the Oil and Gas Sector." Press Release, May 12. https://archive.epa.gov/epa/newsreleases/epa-releases-first-ever-standards-cut-methane-emissions-oil-and-gas-sector.html.

climate policies and actions consistent with the goals of the Paris Agreement are also consistent with long-term economic growth and a healthy job market. Decades of empirical evidence debunk the simplistic narrative that environmental protections are bad for the economy. Given that the growth or contraction of the U.S. economy is driven by broad macroeconomic factors, the net effects of climate policies on GDP and employment are likely to be relatively small compared to the size of the economy.

In fact, when designed well, strong climate action can have a net positive impact on U.S. GDP and employment. For example, efficiency policies can increase energy and resource productivity. Improved low-carbon technologies can lower lifetime energy costs compared to fossil fuel technologies. Although there will be a reduction in fossil fuel sales, during the low-carbon transition there will be an increase in investments in areas like clean energy infrastructure and natural lands, which can drive long-term growth.

Multiple economic models have investigated the effect of climate action on U.S. GDP. While such models are helpful, it is important to note that they have significant limitations that make them tend to underestimate the economic benefits of climate action. Today's models fail to fully capture the potential benefits of disruptive change and gains from innovation and learning. They generally do not consider the risks of climate impacts damaging the economy (further discussed in Chapter 3, Section 3). And they often do not adequately reflect the air quality and health benefits of reducing GHG emissions (further discussed in Chapter 3, Section 2).

The range of models has found that the impacts of climate action on GDP will be minimal, with only slight changes in one direction or the other (Table 3). On the high end, ICF

Table 3 | **Studies on GDP Impacts of Climate Action**

SOURCE	GDP IMPACTS IN 2030	SCENARIO
New Climate Economy (2018)[a]	U.S. GDP up 0.4% in 2030 compared to baseline	2°C
ICF International 2015[b]	U.S. GDP up 0.6% in 2030 compared to baseline	2°C
Vandyck et al. 2016[c]	U.S. GDP down 0.69% in NDC scenario and down 0.7% in 2°C scenario in 2030 compared to baseline	2°C and Paris NDCs
Liu et al. 2019[d]	U.S. GDP down about 0.5% below baseline in 2030	Paris NDCs
Mani et al. 2018[e]	U.S. GDP down 0.62% below baseline in 2030; only 0.28% below baseline if renewable prices decline 25%	Paris NDCs
Aldy et al. 2017[f]	U.S. GDP down 0.39% in 2025 compared to baseline	Paris NDCs

Note: GDP = gross domestic product; NDC = nationally determined contribution. These models are limited because they do not fully capture the economic risks of inaction on climate change, the health benefits of reducing greenhouse gases, or the potential for dynamic low-carbon innovation.

Sources:

a. Cambridge Econometrics. Forthcoming. "2018 Report for the Global Commission on the Economy and Climate: Modeling Technical Note." Modeling Technical Note for New Climate Economy Report. Cambridge, UK: Cambridge Econometrics.

b. ICF International. 2015. *Economic Analysis of U.S. Decarbonization Pathways: Summary of Findings*. Prepared for NextGen Climate America. Fairfax, VA: ICF International. https://nextgenpolicy.org/wp-content/uploads/2015/11/ICF-Study-Summary-of-Findings-Decarb-Econ-Analysis-Nov-5-2015.pdf.

c. Vandyck, T., K. Keramidas, B. Saveyn, A. Kitous, and Z. Vrontisi. 2016. "A Global Stocktake of the Paris Pledges: Implications for Energy Systems and Economy." *Global Environmental Change* 41 (November): 46–63. https://doi.org/10.1016/j.gloenvcha.2016.08.006.

d. Liu, W., W. McKibbon, A. Morris, and P. Wilcoxen. 2019. "Global Economic and Environmental Outcomes of the Paris Agreement." Climate and Energy Economics Discussion Paper. Washington, DC: Brookings Institution. https://www.brookings.edu/wp-content/uploads/2019/01/ES_20190107_Paris-Agreement.pdf.

e. Mani, M., Z. Hussein, B. Gopalakrishnan, and D. Wadhwa. 2018. "Paris Climate Agreement and the Global Economy: Winners and Losers." Policy Research Working Paper WPS 8392. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/705871522683196873/Paris-climate-agreement-and-the-global-economy-winners-and-losers.

f. Aldy, J., W. Pizer, and K. Akimoto. 2017. "Comparing Emissions Mitigation Efforts across Countries." *Climate Policy* 17 (4): 501–15. https://doi.org/10.1080/14693062.2015.1119098.

International finds that climate action consistent with 2°C could lead to a U.S. GDP in 2030 that is 0.6 percent higher than the reference case.[138] On the low-end, Vandyck et al. find that it could lead to a U.S. GDP in 2030 that is 0.7 percent below the reference case[139]—though it should be noted that this still means that GDP in 2030 will be higher than it is today.

Digging deeper into one of these models, the 2018 New Climate Economy report estimated the effects of limiting global warming to below 2°C. In its scenario, the United States reduces its CO_2 emissions 56 percent below 2005 levels by 2030, on track for 88 percent below 2005 levels by 2050. It implements a range of policies, including putting a price on carbon, phasing out fossil fuel subsidies, improving energy efficiency, restoring degraded lands, accelerating the uptake of EVs, and increasing the use of clean energy. If these ambitious climate efforts had begun in 2018, the cumulative direct economic gain for the United States from 2020 to 2030 would have been worth nearly $3 trillion (2017$). By 2022, U.S. GDP would have been at least 1.8 percent higher than it would be in the business-as-usual scenario. In 2030, the difference would not have been as large, but GDP still would have been at least 0.4 percent higher with climate action than without. Of course, the timeline for these benefits has been delayed because the United States did not enact comprehensive federal climate policies in 2018, and it seems likely these policies will not be enacted until 2021 at the earliest.

Most of these analyses have focused on the near term, whereas the longer-term economic impacts will depend on how successfully the United States transitions from being one of the top global fossil fuel producers to a clean energy producer for domestic and global markets. It also will depend on how fast the United States starts moving: the longer it waits, and the more capital stock that is locked in, the more abrupt the transition will have to be to get to a low-carbon economy, which could increase costs.

Moving from GDP to employment, the economic models have found that climate action in the United States is also compatible with a healthy job market. Until recently, it was difficult to determine how large-scale climate action would affect jobs because of limitations in the most common research methods. However, dynamic new economic models, such as the E3ME model used in the 2018 New Climate Economy report, are better at evaluating the effects on employment and labor force participation. Like the GDP estimates, the employment estimates are still likely to be underestimating the positive effects.

The models have found that the overall effects of climate policies on total U.S. employment will be small, with the total number of jobs ranging from 0.25 percent below the baseline to 0.6 percent above the baseline in 2030 (see Table 4). Although there will be job losses in fossil fuel sectors, those effects will be balanced out—if not exceeded by—the millions of clean energy jobs that will be created from low-carbon investment, likely leading to a small net increase in total employment in the next decade under climate policies.

Looking specifically at the modeling from the 2018 New Climate Economy report, it finds that if strong climate action had started in 2018, the net impact on employment would have been positive over the next decade, with job creation particularly concentrated in the near term. By 2022, the total number of U.S. jobs would have been at least 1.8 million higher than the reference case as investment grew and workers built out new low-carbon infrastructure (1.1 percent higher than the reference case). In 2025, there would have been at least 940,000 more jobs (0.5 percent higher than the reference case). In 2030, employment would have lined up again with the business-as-usual scenario. The effects of climate policy were expected to have a much smaller impact on employment than other macroeconomic factors in the longer term, but even using conservative methodology, such policies would create millions of new jobs in the short term. This type of short-term job benefit would be especially helpful in recovering from the economic effects of the COVID-19 pandemic.

The reports discussed above were written before the COVID-19 crisis began and unemployment rose, but there has been some early research on the economic impacts of new U.S. clean energy stimulus spending. New economic analysis from the Political Economy Research Institute, prepared for the Sierra Club, estimates that large public investments of $320 billion per year in clean energy and agriculture programs could create 4.5 million gross jobs per year for 10 years, and $260 billion every year for upgrading infrastructure more broadly could create an additional 4.6 million gross jobs every year for 10 years.[140] This includes 3.2 million gross jobs per year in renewable energy, 700,000 in energy efficiency, and 500,000 in land restoration and agriculture.[141] These investments would put the United States on track to reduce emissions in line with the Paris Agreement. While the model does not include wage, benefits, or contract security parameters, the report explains how the jobs created should follow environmental, labor, and equity standards.

Table 4 | **Studies on Net Employment Impacts of Climate Action**

SOURCE	GDP IMPACTS IN 2030	SCENARIO
New Climate Economy (2018)[a]	U.S. employment up by 1.1% compared to baseline in 2022, and at the baseline in 2030	2°C
Montt et al. 2018[b]	U.S. employment up 0.47% in 2030 in 2°C scenario compared to 6°C scenario	2°C
ICF International 2015[c]	U.S. employment up 0.6% in 2030 compared to baseline in high renewables scenario; U.S. employment up 0.5% in 2030 compared to baseline in mixed-resource scenario	2°C
Liu et al. 2019[d]	U.S. employment down by about 0.25% compared to baseline in 2030	Paris NDCs

Note: NDC = nationally determined contribution. These models are limited because they do not fully capture the economic risks of inaction on climate change, the health benefits of reducing greenhouse gases, or the potential for dynamic low-carbon innovation.

Sources:

a. Cambridge Econometrics. Forthcoming. "2018 Report for the Global Commission on the Economy and Climate: Modeling Technical Note." Modeling Technical Note for New Climate Economy Report. Cambridge, UK: Cambridge Econometrics.

b. Montt, G., K. Wiebe, M. Harsdorff, M. Simas, A. Bonnet, and R. Wood. 2018. "Does Climate Action Destroy Jobs? An Assessment of the Employment Implications of the 2-degree Goal." *International Labour Review* 157 (4): 519–56. https://doi.org/10.1111/ilr.12118.

c. ICF International. 2015. *Economic Analysis of U.S. Decarbonization Pathways: Summary of Findings*. Prepared for NextGen Climate America. Fairfax, VA: ICF International. https://nextgenpolicy.org/wp-content/uploads/2015/11/ICF-Study-Summary-of-Findings-Decarb-Econ-Analysis-Nov-5-2015.pdf.

d. Liu, W., W. McKibbon, A. Morris, and P. Wilcoxen. 2019. "Global Economic and Environmental Outcomes of the Paris Agreement." Climate and Energy Economics Discussion Paper. Washington, DC: Brookings Institution. https://www.brookings.edu/wp-content/uploads/2019/01/ES_20190107_Paris-Agreement.pdf.

The takeaway is that climate action can be consistent with a strong American economy and, in the right circumstances, can even be an engine of additional economic growth and jobs (Box 4). By contrast, delaying action can expose the United States to economic damages and risks. Chapter 5 discusses further the distributional effects and transitional considerations that must be made to ensure that the job effects of climate action are properly addressed.

Health and Ecosystem Benefits

When looking at the costs and benefits of taking action on climate change, it is important to consider the human toll of deaths from air pollution as well as other adverse impacts on the environment. Climate change and air pollution are two separate problems, though both are consequences of the combustion of fossil fuels. Several studies demonstrate that climate action, in addition to reducing global warming, will create significant health and ecosystem benefits from air and water quality improvements in the United States. This adds further evidence that climate policies make economic sense on top of the employment and economic development benefits discussed above. In addition, a growing body of research suggests that air pollution increases the likelihood of contracting respiratory infections such as COVID-19 and the severity of the symptoms.[142]

Burning fossil fuels contributes to air pollution through nitrogen oxide, sulfur dioxide, ground-level ozone, and fine particulate matter ($PM_{2.5}$). These have deadly effects for Americans. More than 4 in 10 Americans live in counties that experienced unhealthy ozone or particulate pollution from 2015 to 2017.[143] $PM_{2.5}$ and ozone pollution are estimated to have caused 107,500 premature deaths in the United States in 2017.[144] Damages from $PM_{2.5}$ pollution have been valued at around 4–5 percent of U.S. GDP.[145]

Over the last several decades, $PM_{2.5}$ has been steadily decreasing, with important benefits for human health—average life expectancy for an American has increased by several months due to better air quality.[146] This is in large part thanks to EPA regulations through the Clean Air Act. However, there has been backsliding in recent years. After declining by 24 percent between 2009 and 2016, annual average $PM_{2.5}$ in the United States increased by 5.5 percent between 2016 and 2018.[147] Under the Trump administration, the EPA has been weakening the enforcement of air quality regulations and is moving

Box 4 | The Economics of Carbon Pricing

Carbon pricing has been one of the most studied climate policies and will likely be an essential part of a future U.S. climate strategy.[a] California and the 10 states of the Regional Greenhouse Gas Initiative have carbon pricing in place, and more than a dozen other states have introduced carbon pricing legislation.[b] By making polluters pay for environmental harms, carbon pricing incentivizes the economy to shift to less carbon-intensive practices, and to do so in the most efficient way possible.

While the main point of carbon pricing is to shift incentives, it also raises revenue for the government that can be used for a variety of different purposes, such as reducing other taxes, investing in clean energy innovation and sustainable infrastructure, or providing a dividend to households. If done well, it can stimulate additional economic growth as aggregate investment is shifted from fossil fuels to other industries, which then become more productive.[c]

Historical experiences in U.S. states and other countries that have implemented a carbon price shows us that it has been compatible with strong economic growth. Economic models find the same thing. For example, Stanford University's Energy Modeling Forum found that in every scenario it studied across 11 different energy models, an ambitious carbon tax is consistent with positive annual economic growth within 0.1 percent of the baseline rate without a carbon tax.[d] In all of these models, the effects are found even before climate and air pollution benefits are considered.

The most important consideration when designing a carbon price is the distributional impact. Any short-term negative effects should be avoided through revenue recycling and other support, and businesses and consumers should be set up for greater gains later with the help of complementary policies like energy efficiency to reduce fuel spending. In 2019 numerous new carbon pricing proposals were introduced in the U.S. Congress. According to Resources for the Future's Carbon Pricing Calculator, in five of the seven proposals, revenue recycling would lead to net welfare gains for poor and middle-income households.[e] Of the different options, revenue recycling as a per-household dividend provides the largest welfare increase for lower-income households.

Carbon pricing should also be paired with a phasing out of fossil fuel subsidies, which incentivize fossil fuel energy extraction and exploration. The United States provides more than $25 billion per year in direct fossil fuel subsidies.[f] These include tax breaks and public finance, with the majority supporting oil and gas production. About half of new U.S. oil fields that are not yet in development are only profitable with subsidies.[g] The International Monetary Fund considers a more expansive definition of a subsidy: the size of the gap between existing fossil fuel prices and what the prices would be if they fully reflected supply costs plus the taxes needed to reflect environmental externalities such as climate change and air pollution. It finds that the United States implicitly supported fossil fuels to the tune of $649 billion in 2015, 3.6 percent of gross domestic product.[h] Without action, the United States will continue to build fossil fuel infrastructure that causes pollution and climate damages, resulting in stranded assets.

a. Macaluso, N., S. Tuladhar, J. Woollacott, J.R. Mcfarland, J. Creason, and J. Cole. 2018. "The Impact of Carbon Taxation and Revenue Recycling on U.S. Industries." *Climate Change Economics* 9 (1). https://doi.org/10.1142/S2010007818400055.

b. Climate Xchange. n.d. "State Carbon Pricing Network." https://climate-xchange.org/network/. Accessed March 26, 2020.

c. Siegmeier, J., L. Mattauch, and O. Edenhofer. 2018. "Capital Beats Coal: How Collecting the Climate Rent Increases Aggregate Investment." *Journal of Environmental Economics and Management* 88 (March): 366–78. https://doi.org/10.1016/j.jeem.2017.12.006.

d. McFarland, J., A. Fawcett, A. Morris, J. Reilly, and P. Wilcoxen. 2018. "Overview of the EMF 32 Study on U.S. Carbon Tax Scenarios." *Climate Change Economics* 9 (1). https://doi.org/10.1142/S201000781840002X.

e. Resources for the Future. n.d. (Database.) *Carbon Pricing Calculator*. https://www.rff.org/cpc/. Accessed June 1, 2020.

f. Whitley, S., H. Chen, A. Doukas, I. Gençsü, I. Gerasimchuk, Y. Touchette, and L. Worrall. 2018. "G7 Fossil Fuel Subsidy Scorecard." Policy Brief. London: Overseas Development Institute. https://www.odi.org/sites/odi.org.uk/files/resource-documents/12222.pdf.

g. Erickson, P., A. Down, M. Lazarus, and D. Koplow. 2017. "Effect of Subsidies to Fossil Fuel Companies on United States Crude Oil Production." *Nature Energy* 2 (November): 891–98. https://doi.org/10.1038/s41560-017-0009-8.

h. Coady, D., I. Parry, N. Le, and B. Shang. 2019. "Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates." Working Paper 19/89. Washington, DC: International Monetary Fund.

to further roll back clean air standards.[148] Increased economic activity and wildfires are also potential factors driving the change.[149] Meanwhile, the number of premature deaths attributable to ozone have been increasing as hotter summer weather makes ozone more likely to form.[150,151]

Reducing GHG emissions to prevent climate change would also reduce $PM_{2.5}$ and ozone, saving thousands of lives and lowering health costs. Ideally, the United States would strengthen both climate action and air pollution regulations. According to one study, if the United States reduced emissions in a way consistent with the Paris Agreement, it could prevent 14,000 more premature $PM_{2.5}$ deaths per year by 2030 beyond the estimates for current U.S. air pollution regulations.[152] Another study found that even if the United States strengthened its air pollution regulations to a more stringent level, climate action would still lead to an added air pollution benefit, resulting in 8,000 fewer premature deaths from $PM_{2.5}$ and ozone in 2030 and 25,000 fewer in 2050.[153]

In addition to air quality improvements, climate action can lead to benefits for water, soil, and biodiversity. Natural climate solutions can preserve and restore natural and working lands to increase their ability to store carbon, but they also have myriad cobenefits. For example, using cover crops decreases soil erosion, which increases the depth of usable soil, and increases its ability to retain water, so less irrigation is needed. Improved manure management increases soil nutrients and limits nitrogen and phosphorus runoff that pollutes rivers and has caused the Gulf of Mexico's "dead zone." Likewise, reforestation can create wildlife corridors and improve water availability to mitigate drought.[154]

Coal ash waste is one of the largest sources of industrial pollution and contaminates water supplies. Ninety-one percent of U.S. coal plants that post monitoring data are currently contaminating groundwater with unsafe levels of toxic substances.[155] There is also a risk of spills, like the 2008 coal ash spill in Kingston, Tennessee, which released 5 million cubic yards of coal ash into the nearby river and housing developments.[156] Phasing out coal power will prevent the accumulation of pollution at coal ash sites, but existing coal ash ponds also must be cleaned up.

The Costs of Inaction and Delay

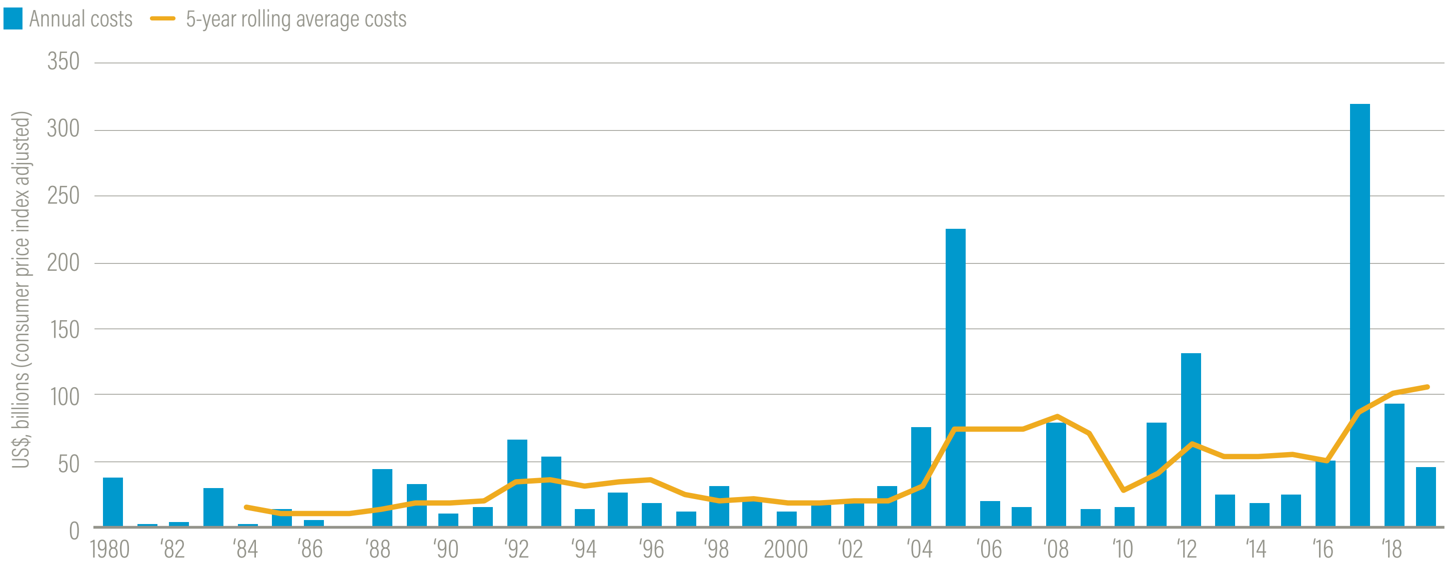
The COVID-19 pandemic has caused many of us to rethink the way we approach risk. Both climate change and COVID-19 are threat multipliers that, if left unchecked, can spiral out of control and overwhelm a nation's ability to respond. Countries that prepared ahead of time for a pandemic have had far greater success in limiting its spread and economic impact. Likewise, responding to climate change as early as possible will limit the economic consequences.

Climate change impacts are already taking a human and financial toll on communities across the United States and are projected to worsen. If the United States leads international efforts to limit temperature rise, it can largely avoid these damages.

In recent years, record-breaking wildfires, hurricanes, heat waves, and floods have devastated the United States. These types of extreme weather events are becoming more likely because of climate change.[157] For example, the frequency of the most damaging hurricanes has tripled since 1900 due to climate change.[158] Natural disasters have become more costly over time as populations and property values rise, and climate change has increased their frequency and intensity (see Figure 16). During the 2010s, major extreme weather and climate disasters in the United States caused $802 billion in damages.[159] This is far higher than the $510 billion in damages during the 2000s, $270 billion during the 1990s, and $173 billion during the 1980s (adjusted for inflation). To give some recent examples, in 2017 Hurricane Maria imposed more than $90 billion in damages on Puerto Rico. In 2018 Hurricanes Michael and Florence each caused about $25 billion in damages.[160] In 2018–19, wildfires in California also caused about $40 billion in damages, the worst in history.[161] In 2019, the Pacific Gas and Electric Company enacted large-scale power cuts in parts of California as a preventive measure to curb wildfires. By one estimate, this resulted in $2.5 billion in economic losses because many businesses and industries could not operate and particularly affected low-income communities.[162]

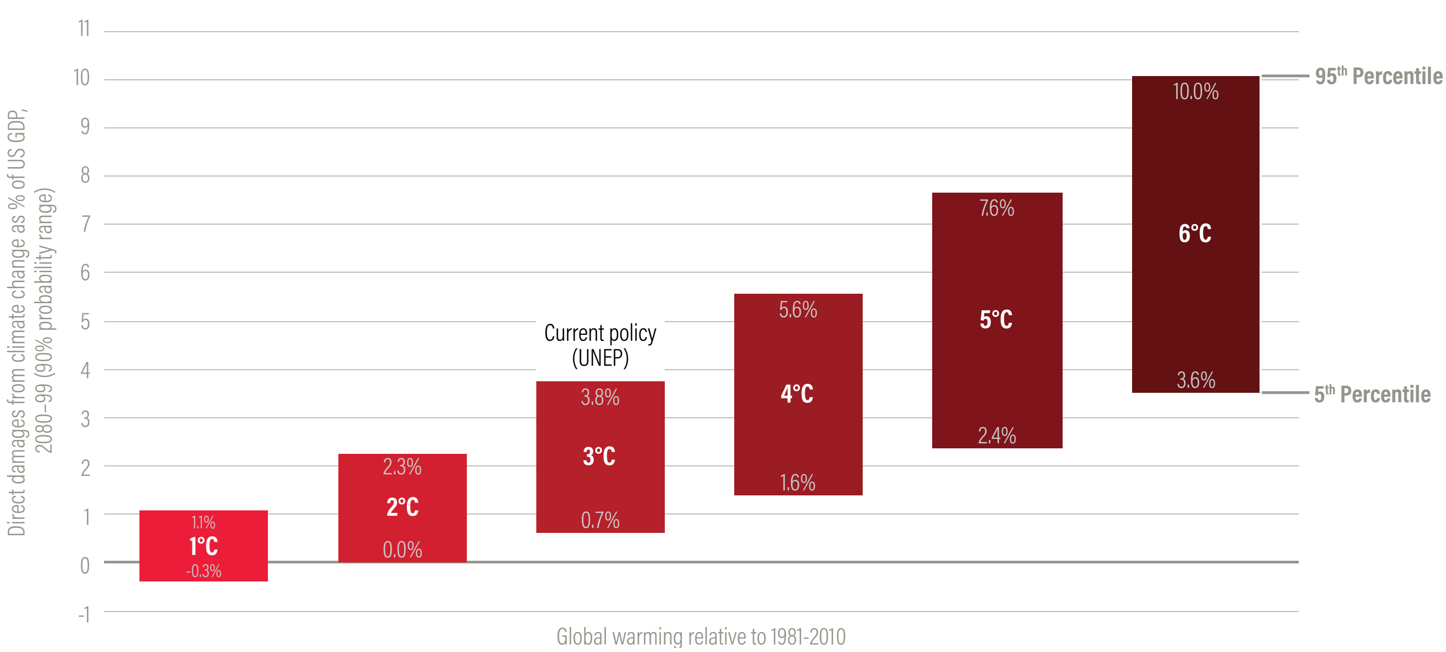
More intense and frequent natural disasters will not be the only climate-related costs. Higher temperatures will lead to higher health care costs and thousands of heat-related deaths. Crop yields will decline in parts of the country. Roads, rails, and other infrastructure will be damaged. High temperatures can also slow growth rates in sectors not typically considered to be affected by heat—such as food services, insurance carriers, retail, wholesale, construction, and real estate—by causing labor productivity to decline.[163] An analysis of fluctuations in U.S. temperatures found that from 1957 to 2012, when a state's average summer temperature was 1°F (0.6°C)

Figure 16 | The Cost of Extreme Weather and Climate-Related Events



Source: National Centers for Environmental Information. 2020. *Billion-Dollar Weather and Climate Disasters: Time Series.* Asheville, NC: National Centers for Environmental Information, National Oceanic and Atmospheric Administration. https://www.ncdc.noaa.gov/billions/time-series.

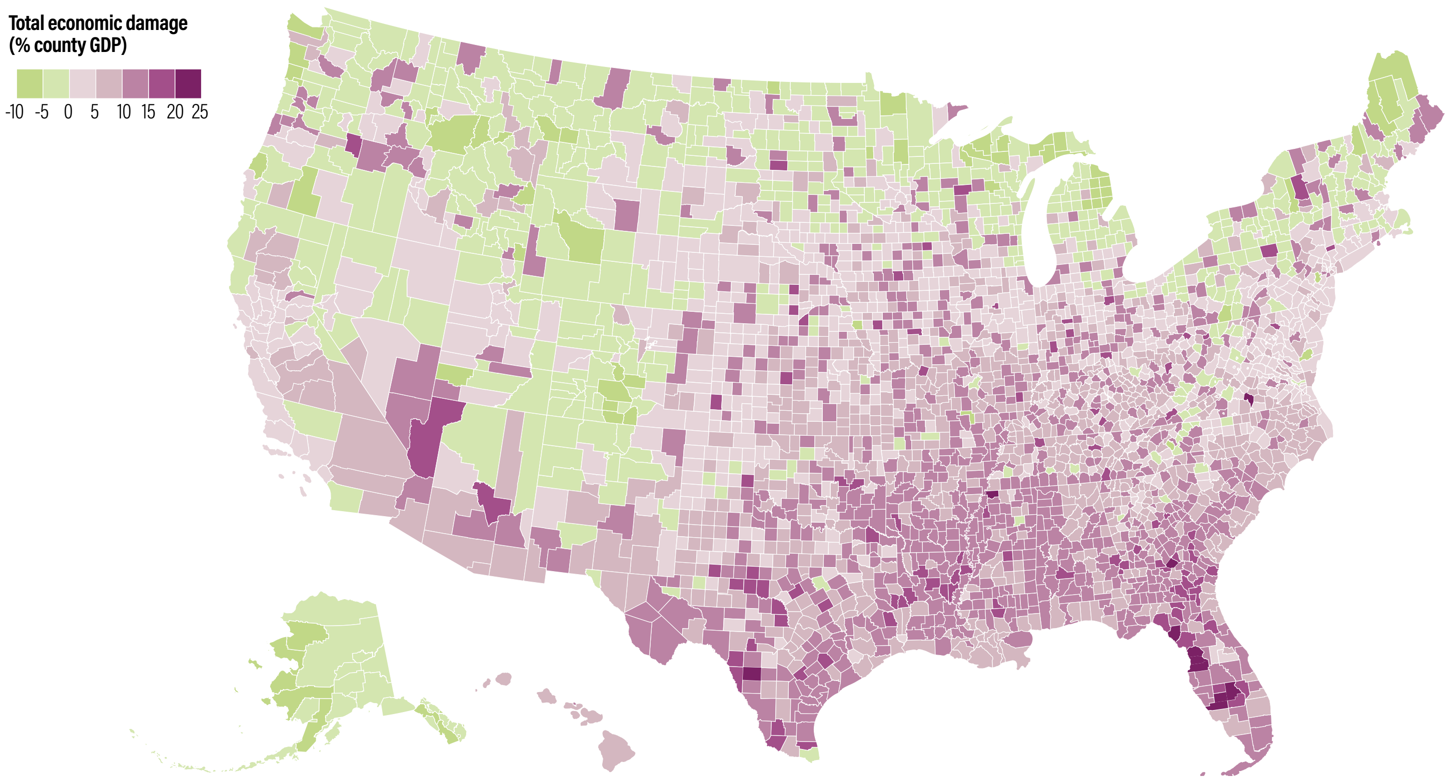
Figure 17 | U.S. Economic Damages at Different Levels of Global Warming



Note: GDP = gross domestic product; UNEP = United Nations Environment Programme. Average global temperatures were already 0.63°C higher in 1981–2010 compared to preindustrial levels, which are generally used as the reference point for the Paris Agreement's goals (Climate Change Service. 2019. "Last Four Years Have Been the Warmest on Record—and CO_2 Continues to Rise." January 7. https://climate.copernicus.eu/last-four-years-have-been-warmest-record-and-co2-continues-rise).

Sources: Hsiang, S., R. Kopp, A. Jina, J. Rising, M. Delgado, S. Mohan, D.J. Rasmussen, et al. 2017. *"Estimating Economic Damage from Climate Change in the United States." Science* 356 (6345): 1362–69. https://doi.org/10.1126/science.aal4369; United Nations Environment Programme. 2019. *Emissions Gap Report 2019*. Nairobi: United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/30797/EGR2019.pdf?sequence=1&isAllowed=y.

Figure 18 | **Estimated Damages from Climate Change, 2080–99**



Source: Hsiang, S., R. Kopp, A. Jina, J. Rising, M. Delgado, S. Mohan, D.J. Rasmussen, et al. 2017. "Estimating Economic Damage from Climate Change in the United States." *Science* 356 (6345): 1362–69. https://doi.org/10.1126/science.aal4369.

higher, the annual growth rate of state-level output was lower by 0.15–0.25 percentage points. This effect was particularly strong in the South.[164]

If the United States does not both mitigate and adapt to climate change, the economic consequences will become even more severe in the future. Economic assessments can evaluate the potential future risks of climate change, but they generally underestimate many of the most serious consequences for lives and livelihoods.[165,166] This is because climate change is a complex global phenomenon that varies across space and time. Capacity to assess future impacts is challenged by the complex interactions between climate, demographics, politics, economics, and land use. Certain types of damages, such as climate-induced migration, ecosystem loss, and changes to water availability are not yet included in damage estimates. In addition, GHGs are long-lived, which means that today's emissions will affect generations hundreds of years from now, even though the economic assessments do not look that far ahead. Therefore, the current estimates of the economic consequences of climate change impacts are conservative and may not be capturing the true nature and scale of damage to lives and livelihoods.

That said, current estimates do find that there will be serious economic losses from climate change. Hsiang et al. have estimated these damages and found that the more the world warms, the higher the costs will be for the United States (see Figure 17).[167] According to the United Nations Environment Programme (UNEP), if current policies are continued, it would lead to a global mean temperature rise of about 3.5°C above preindustrial levels by 2100 (2.9°C above 1980–2010 levels), with a high range of uncertainty.[168] At this rate, the economic damages to the United States would be around 0.7–3.8 percent of U.S. GDP from 2080 to 2099. With runaway emissions and global warming of 6°C, the damages would be 3.7–10.0 percent of GDP over those two decades. The biggest damages would be from increased premature mortality, but there would also be damages from reduced labor supply, coastal flooding, higher energy demand, Box 5 | **The Cost of Urban Sprawl**

Urban sprawl leads to significant economic costs and makes cities dependent on greenhouse gas–emitting cars. In the United States, urban sprawl is estimated to cost over $1 trillion per year.[a] It increases the costs of public infrastructure and services, traffic congestion, car accidents, pollution, and health care. Sprawl is particularly costly for low-income and disadvantaged groups who rely on walking, cycling, and public transit.[b] Transportation is the largest source of U.S. carbon emissions, and urban sprawl is a big contributor. When combined with poor urban infrastructure, the unchecked sprawl of cities into wetlands and other natural rainwater-absorbing areas also exacerbates the scale and duration of floods.

Compact, coordinated, and connected urban development can benefit the economy by concentrating economic activity, and it also can reduce the economic costs imposed by climate change. Research from the Coalition for Urban Transitions finds that there is a strong positive relationship between higher-density cities and economic activity. In the United States, a 10 percent increase in population density is associated with a 1.9 percent increase in patents per 1,000 people, a 4.6 percent increase in high-skilled wages, a 5.5 percent increase in medium-skilled wages, and a 2 percent per capita decrease in carbon emissions.[c] To achieve these benefits, the United States needs better city planning to promote mixed-use, higher-density development and incentives for Americans to switch from cars to other mobility options.

a, b. Litman, T. 2015. "Analysis of Public Policies That Unintentionally Encourage and Subsidize Urban Sprawl." Working Paper. Washington, DC: New Climate Economy. https://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2016/04/public-policies-encourage-sprawl-nce-report.pdf.

c. Coalition for Urban Transitions. 2019. *Climate Emergency, Urban Opportunity: How National Governments Can Secure Economic Prosperity and Avert Climate Catastrophe by Transforming Cities*. Washington, DC: Coalition for Urban Transitions, World Resources Institute. https://urbantransitions.global/wp-content/uploads/2019/09/Climate-Emergency-Urban-Opportunity-report.pdf.

higher crime, and lower crop yields.[169] For comparison, during the Great Recession, real U.S. GDP fell 4.3 percent from the end of 2007 to mid-2009.[170] The economic consequences of climate change would result in ongoing damage rather than a one-time shock.

Mitigation will be essential to avoid these economic impacts. Thousands of lives and billions of dollars can be saved by limiting global warming to 1.5°C or 2°C above preindustrial levels and avoiding business-as-usual damages. For the remaining damages, the United States must implement adaptation measures.

The impacts of climate change will not be distributed evenly. Areas that are already struggling will be hit the hardest by climate change, thus increasing economic inequality across the country. When ranking U.S. counties by economic and social vitality, the poorest quintile is expected to face losses of 7 percent of county income in 2080–99 under a high-emissions scenario (RCP8.5), while the richest quintile is expected to face losses of less than 1.5 percent of county income.[171]

On a regional basis, the South and parts of the Midwest will be the most affected, with the hardest-hit counties losing more than 20 percent of gross county product by 2080–99 in the worst-case scenario (see Figure 18).[172] Agricultural yields will go down in parts of the Midwest. Mortality from extreme temperatures will go up in the South. Coastal damage will increase in the Atlantic states; in Florida, Louisiana, and South Carolina, sea level rise alone will cost 0.6–1.3 percent of gross state product. The South will become poorer compared to the North because a few northern states will see positive economic effects from climate change. The North will also see consequences, such as worse air quality and more asthma-related hospital visits due to increased allergens.[173] The Northwest and Northern Plains will be at greater risk of floods that are currently 1-in-100-year events. The good news is that with climate change mitigation, all regions of the country can avoid some of these economic damages.

In addition to regional disparities, climate change will have a disproportionate and unequal impact on minority and low-income communities.[174] People in these communities often live in areas with the worst air quality and are most susceptible to flooding or other weather hazards. Lower-income minority residents are also likelier than wealthier residents to live near sources of significant pollution, including landfills, power plants, and incinerator plants. These existing inequalities will only be exacerbated by not taking action on climate change. See Section 5 for more detail on how to ensure the benefits of climate policies are shared by all.

The Investment Needs for a Low-Carbon Transition

Deep decarbonization in the United States will require additional investment in low-carbon infrastructure such as clean energy power plants, green buildings, and EVs. The U.S. Federal Reserve has lowered interest rates to zero to respond to the economic impacts of the COVID-19 pandemic. This makes it a particularly good opportunity to invest in long-term infrastructure for a low-carbon transition.

Several studies have examined the net energy system costs (investments minus savings) of getting the United States on a sustainable pathway. For example, the Risky Business Project looked at a scenario in which emissions are reduced 80 percent below 1990 levels by 2050 (see Figure 19). Compared to a high-carbon reference case, annual economy-wide investment would increase by 0.4–2.0 percent of GDP over the period 2020–50. But these investments would be increasingly offset by decreased spending on fossil fuels. Net energy system costs would peak during the mid-2030s. By the 2040s, there would be net energy system savings worth hundreds of billions of dollars per year, and these savings would be on a trajectory to continue far beyond that.

This analysis generally aligns with other estimates of the investment needs for the low-carbon transition (see Table 5). A number of studies have found that ambitious climate action will have investment costs equivalent to 2 percent of GDP at the most. A recent study from Asia-Pacific Economic Cooperation (APEC) estimated that the United States will experience net savings rather than net costs in a 2°C world. This is because the $2.6 trillion in additional investments will be outweighed by the $5.5 trillion in fossil fuel savings from 2017 to 2050.[175] It should be noted that, for all of these studies, these net costs or savings

Table 5 | **Studies of U.S. Energy System Net Costs on a Low-Carbon Pathway Compared to Reference Case**

SOURCE	FINDINGS	SCENARIO
APEC 2019[a]	Cumulatively, $2.6 trillion in capital investments and $5.5 trillion in fuel savings from 2017 to 2050	2°C scenario
Haley et al. 2019[b]	Average annual net costs peak in 2040 at about $600 billion, less than 2% of gross domestic product (GDP) per year, and are down to about $400 billion in 2050	Carbon dioxide limited to 350 parts per million; net negative emissions by 2050, base scenario (1°C compliant)
Gowrishankar and Levin 2017[c]	Average annual net costs of $22 billion for 2015–50; by 2050, there is an annual net savings of $30 billion	80% emissions reduction by 2050 (2°C compliant)
Burchardt et al. 2018[d]	Net annual investments of 1.5% of GDP from 2015 to 2050.	2°C scenario
Duane et al. 2016[e]	Annual economy-wide investment increases by 0.4–2.0% of GDP; average annual net costs peak during the mid-2030s; during the 2040s, there are annual net savings worth hundreds of billions of dollars	80% emissions reduction below 1990 levels by 2050, mixed-renewables scenario (2°C compliant)
Williams et al. 2015[f]	Annual net costs of $320 billion in 2050, about 0.8% of projected GDP	80% emissions reduction by 2050 (2°C compliant)

a. Asia-Pacific Economic Cooperation. 2019. *APEC Energy Demand and Supply Outlook.* 7th ed. Vol. 2. Singapore: Asia-Pacific Economic Cooperation.

b. Haley, B., R. Jones, G. Kwok., J. Hargreaves, J. Farbes, and J. Williams. 2019. *350 PPM Pathways for the United States*. San Francisco: Evolved Energy Research. https://docs.wixstatic.com/ugd/294abc_95dfdf602afe4e11a184ee65ba565e60.pdf.

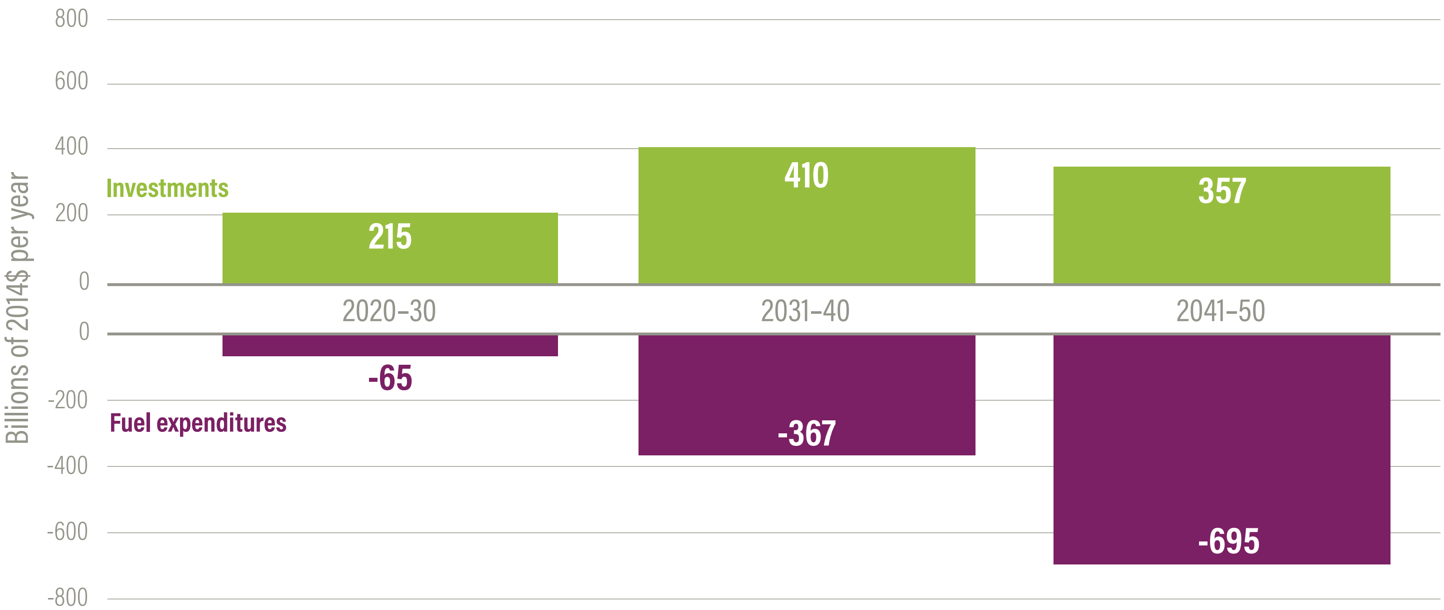
c. Gowrishankar, V., and A. Levin. 2017. *America's Clean Energy Frontier: The Pathway to a Safer Climate Future*. New York: Natural Resources Defense Council. https://www.nrdc.org/sites/default/files/americas-clean-energy-frontier-report.pdf.

d. Burchardt, J., P. Gerbert, S. Schönberger, P. Herhold, and C. Brognaux. 2018. *The Economic Case for Combatting Climate Change*. Washington, DC: Boston Consulting Group, Henderson Institute. https://www.bcg.com/publications/2018/economic-case-combating-climate-change.aspx.

e. Duane, T., J. Koomey, K. Belyeu, and K. Hausker. 2016. *From Risk to Return: Investing in a Clean Energy Economy*. Risky Business Project. https://riskybusiness.org/site/assets/uploads/sites/5/2016/10/RBP-FromRiskToReturn-WEB.pdf.

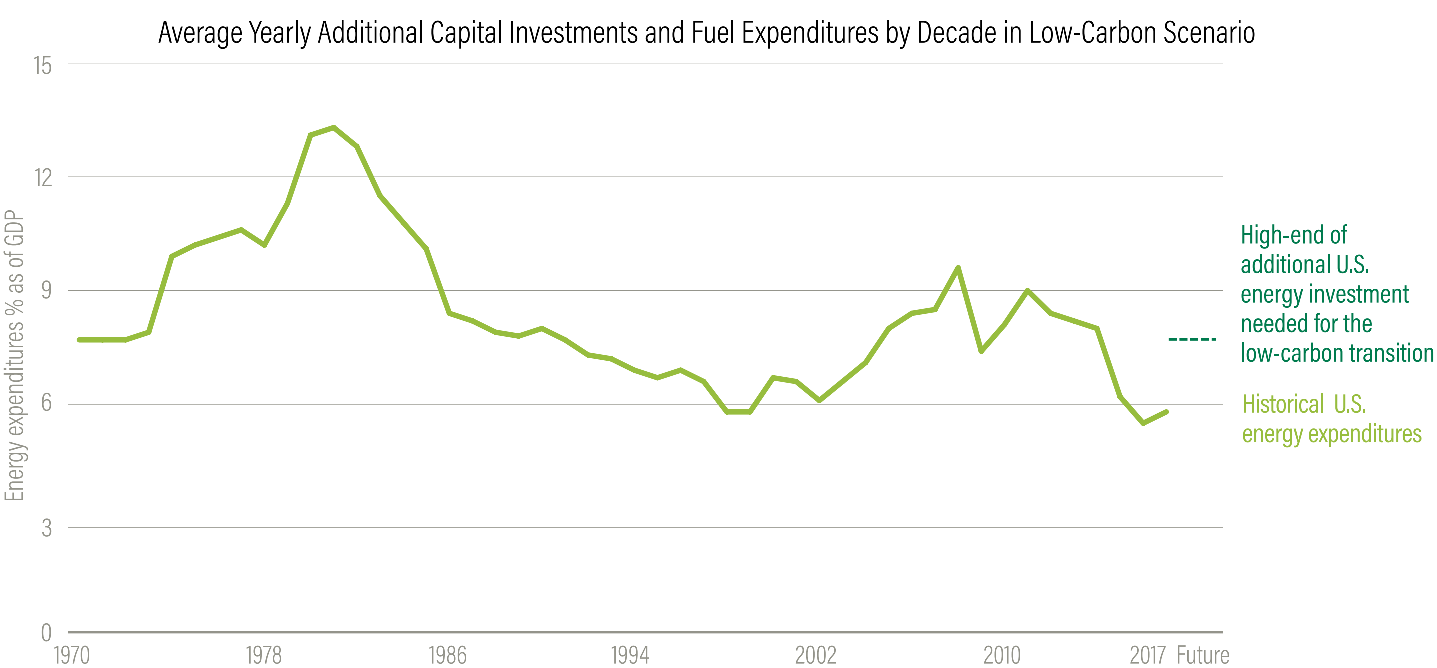
f. Williams, J.H., B. Haley, and R. Jones. 2015. *Policy Implications of Deep Decarbonization in the United States*. Vol. 2 of *US 2050 Report*. San Francisco: Energy and Environmental Economics; Paris: Deep Decarbonization Pathways Project. http://usddpp.org/downloads/2015-report-on-policy-implications.pdf.

Figure 19 | Average Yearly Additional Capital Investments and Fuel Expenditures by Decade in Low-Carbon Scenario



Source: Duane, T., J. Koomey, K. Belyeu, and K. Hausker. 2016. *From Risk to Return: Investing in a Clean Energy Economy.* Risky Business Project. https://riskybusiness.org/site/assets/uploads/sites/5/2016/10/RBP-FromRiskToReturn-WEB.pdf.

Figure 20 | Expected Additional Energy Investment Needs Are Well within Historical Norms



Note: GDP = gross domestic product.

Source: U.S. Energy Information Administration. n.d. "Energy Consumption, Expenditures, and Emissions Indicators Estimates." Annual Energy Review. https://www.eia.gov/totalenergy/data/annual/index.php; WRI analysis.

do not take into account the value of climate, ecosystem, or human health benefits. The older sources also likely overestimate the investment needs because they use outdated technology assumptions; multiple studies use EIA cost data from 2013, which is eons old in the fast-moving world of clean energy technology.

The main takeaway is that the investment needed to act on climate change is much smaller than many have claimed. In addition, it is largely offset by reduced fossil fuel expenditures, with net energy costs down in the longer term. Even at the high end of the estimates, additional energy spending equivalent to 2 percent of U.S. GDP would not push total energy spending outside of historical norms. The total private and public energy spending as a share of GDP has been as high as 13 percent during the early 1980s and as low as 6 percent today (see Figure 20).[176]

4. RENEWING ECONOMIC VITALITY IN KEY SECTORS AND GEOGRAPHIES

Recharging American Manufacturing Competitiveness

Throughout much of the 20th century, the United States was a global leader in innovation and manufacturing. Strategic public and private investment in research, development, and the commercialization of advanced technologies played a crucial role in creating new industries and millions of jobs for American workers.

However, the nation's manufacturing sector has experienced significant disruptions over the last two decades, including sharp job losses. The U.S. share of global manufacturing declined from 28 percent in 2002 to about 18 percent in 2016.[177] In addition, the United States has lost much of the capacity to manufacture the advanced technologies that were first invented in the country.[178] The COVID-19 pandemic has further stalled the nation's manufacturing sector due to factory closures, supply chain disruptions, and declining demand. Altogether, these challenges pose significant long-term economic risks to the nation's ability to generate economic growth through innovation leadership.

The decline of U.S. manufacturing is not set in stone. In low-carbon industries, demand is growing and new technologies are emerging, with the potential to boost U.S. manufacturing and open pathways to increased American competitiveness. The COVID-19 outbreak, coupled with an ongoing trade war and tariffs, has further highlighted the challenges of dependency on one country or one region for sourcing materials and parts for building a final product.[179] The U.S. renewable industry is facing significant disruptions because many manufacturers of critical components for wind turbines, solar PV panels, and batteries are based in Asia. It is in the long-term interest of the United States to have the essential building blocks of the low-carbon economy be manufactured domestically.

Manufacturing Underpins Innovation and Competitiveness

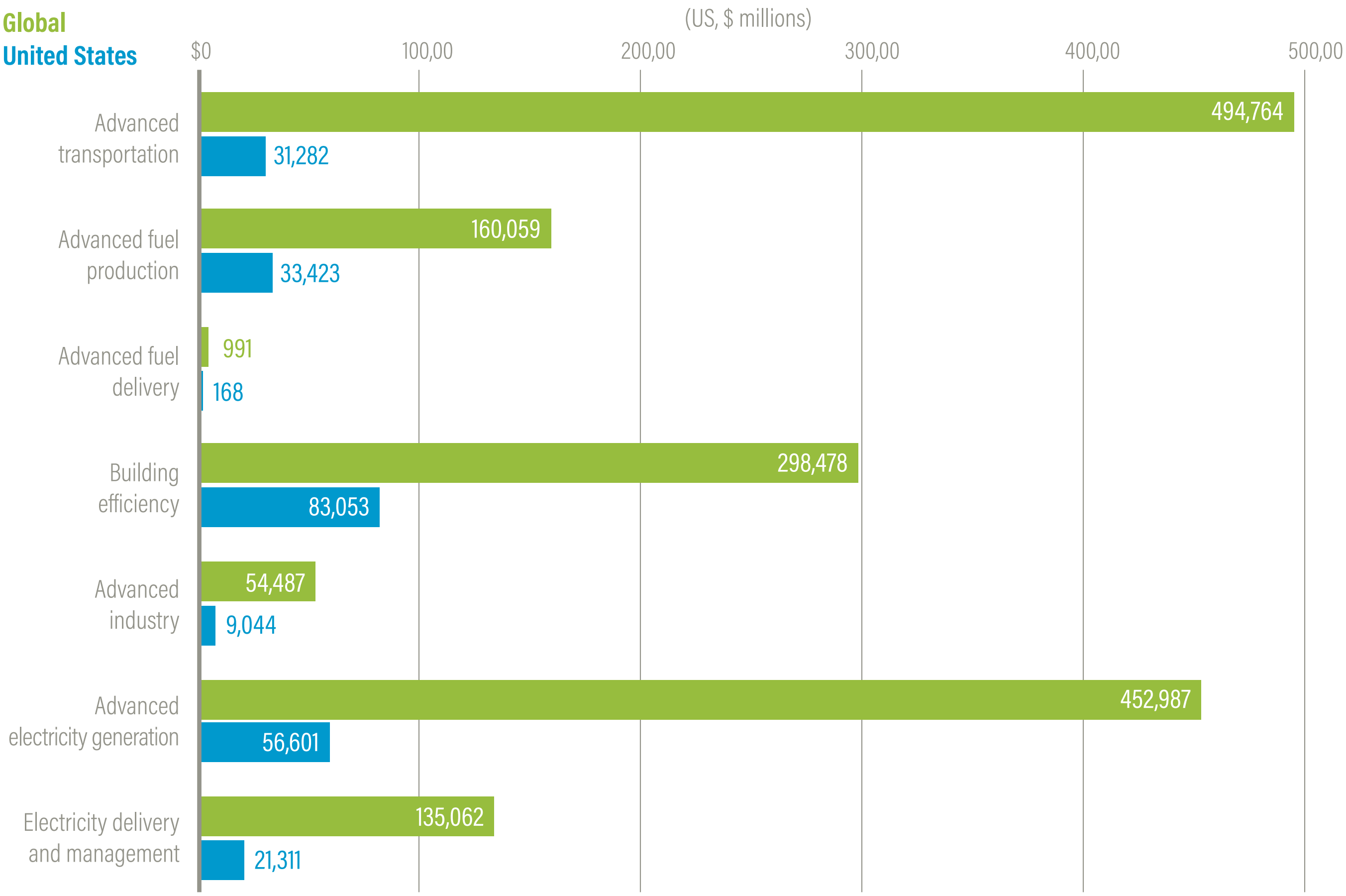
Technological innovation is the principal driver of long-term economic growth. U.S. manufacturing companies are responsible for two-thirds of the nation's private sector spending on research and development (R&D), driving more innovation than any other sector.[180] A complex web of collective R&D, engineering, and manufacturing capabilities helps explain the crucial links between manufacturing innovation and the health of the U.S. economy.[181] Locating R&D and manufacturing together presents opportunities for joint problem solving and knowledge exchange, all of which can lead to process innovations and new product development.[182]

When manufacturing jobs are relocated abroad, their impact is not the same as a relocation of low-skilled jobs abroad. It also causes the loss of engineering and production know-how—and eventually innovation. Take the example of lithium-ion batteries, which power everything from laptops and cell phones to grid storage systems to EVs. After federal investments in R&D during the 1990s made the technology more feasible, U.S. companies decided to offshore battery production to East Asian countries.[183] Now, these countries, and especially China, have a large production advantage, which may also enable them to take the leading position on the technology side.[184] By early 2019, of 316 gigawatt-hours of global lithium cell manufacturing capacity, China accounted for 73 percent and the United States for 12 percent.[185] Ignoring the strong links between manufacturing and innovation risks eroding America's competitive edge in both current and future low-carbon industries.[186] In fact, failure to support the development and deployment of clean manufacturing alternatives can lead to further offshoring of jobs and dependence on foreign technologies.[187]

Securing a Place in the Growing Cleantech Market

By innovating, engineering, and manufacturing low-carbon technologies, the United States can secure a share in the booming domestic and global cleantech market.[188]

Figure 21 | **Global and U.S. Advanced Energy Revenue, 2018**



Source: Advanced Energy Economy. 2019. *Advanced Energy Now: 2019 Market Report.* Report prepared by Navigant Research. Washington, DC: Advanced Energy Economy.

But the longer the United States waits, the harder this will be to do. Right now, America is home to only 1 of the top 10 solar PV manufacturers and 1 of the top 8 producers of EVs.[189]

The U.S. market for manufactured goods is still one of the largest in the world. The U.S. advanced energy market, for instance, has grown to a $238 billion industry, dominated by technologies in the building efficiency and advanced electricity generation sectors (see Figure 21).[190] Its annual revenue is roughly equal to that of aerospace manufacturing and is double the biotechnology industry. The 11 percent growth over 2017 was nearly four times the growth rate of the U.S. economy overall. The DOE's *Benchmarks of Global Clean Energy Manufacturing* has found that the United States has the highest demand for clean energy technologies among a comparison of 12 countries.[191] This is promising for domestic production growth given that manufacturing companies often want to be located as close to their customers as possible, especially if they produce technologies like batteries and wind turbines, which are difficult and expensive to move.

Demand is also rising abroad. A $23 trillion market for climate-smart investments will develop between now and 2030 in 21 emerging markets as those countries work to meet the climate goals outlined in the Paris Agreement.[192] The European Union is planning to implement a border adjustment mechanism that would impose a carbon tax on products from other countries with less strict climate policies.[193] The United States will be left on the sidelines if it cannot retool its economy to meet the needs of this growing market. Developing a domestic market for clean technologies and focusing their application in foreign markets positions American companies to incubate innovative products with massive growth potential and capture a good share of the global market.[194]

Low-Carbon Manufacturing and Jobs

A number of specific technologies and products that are critical to the U.S. low-carbon economy have high

Box 6 | Making a Concrete Change towards Low-Carbon Cement

Cement, which is used to make concrete, accounts for about 1 percent of U.S. greenhouse gas emissions and will be among the most difficult sectors to decarbonize.[a] Forty percent of the industry's emissions come from using coal and other fossil fuels to heat the cement kilns to 1,500°C. The other 60 percent of emissions are from the chemical reactions that occur when the limestone breaks down into calcium oxide. But new companies are attempting to change how the cement industry works. New Jersey–based Solidia, for example, has developed a way to reduce the carbon footprint of concrete by 70 percent by using a process that requires less heat, produces fewer chemical emissions, and sequesters captured carbon dioxide (CO_2) as part of the concrete curing process. Last year, Solidia and LafargeHolcim (the largest cement producer in the world) announced a commercial venture to supply U.S. concrete producers with reduced CO_2 cement.[b] They are now supplying EP Henry's Wrightstown, New Jersey, plant with low-carbon cement, which, in turn, is manufacturing low-carbon precast concrete products that are being installed in the northeastern and mid-Atlantic United States.

a. U.S. Environmental Protection Agency. 2020. "Greenhouse Gas Reporting Program (GHGRP)." January 10. www.epa.gov/ghgreporting.

b. Slowey, K. 2019. "LafargeHolcim Launches CO_2-Reducing Cement Business." Construction Dive. August 9. https://www.constructiondive.com/news/lafargeholcim-launches-co2-reducing-cement-business/560589/.

manufacturing intensity. One study estimated that 26 percent of the clean economy's 2.7 million jobs in 2010 were in manufacturing, compared to 9 percent of U.S. jobs overall.[195] In some clean economy sectors, such as EV technologies, water-efficient products, green chemical products, energy efficient appliances, lighting, and recycled-content products, the share was even higher.

These manufacturing jobs have room to grow. For each full-time-equivalent job in manufacturing, there are 3.4 full-time-equivalent jobs created in nonmanufacturing industries, the highest multiplier in the U.S. economy.[196] Manufacturing workers earn 13 percent more in hourly compensation (wages and benefits) than comparable workers earn in the rest of the private sector, making manufacturing a source of good jobs.[197] More importantly, manufacturing jobs have historically offered opportunities for workers without college degrees to gain technical skills and climb the economic ladder.[198]

With smart policies, the U.S. manufacturing sector can be the location for high-wage, high-skilled jobs, making low-carbon technologies for use at home and abroad. One example is low-carbon alternatives to hydrofluorocarbons (HFCs), which are used in refrigeration, air-conditioning, aerosols, and other applications, and which have an outsized effect on global warming. If the United States implements the Kigali Amendment to the Montreal Protocol, HFC alternatives could become a job creator for U.S. industry. One study has estimated that phasing down HFCs and accelerating production of HFC alternatives would create an additional 33,000 direct manufacturing jobs in the United States and an additional $12.5 billion in output per year beyond normal industry growth. Counting indirect and induced effects, it would create 150,000 additional jobs and $38.8 billion in additional output.[199] Creating these kinds of job opportunities should be a top-tier economic priority as the U.S. economy begins the long recovery from the economic impacts of COVID-19.

Reducing Emissions from Manufacturing

The U.S. industrial sector is responsible for more than 20 percent of U.S. GHG emissions.[200] The most energy-intensive manufacturing plants in the country, which include chemicals, cement, iron, and steel manufacturing, are responsible for roughly a quarter of that total.[201] This highlights the need for increased attention and urgency in reducing emissions from these highly energy-intensive manufacturing facilities. In addition, improving the energy performance of manufacturing facilities can help them reduce waste and save money, which can be used for capital and workforce investments that make them more productive and competitive.

While energy efficiency and on-site renewable energy can reduce the industrial sector's demands on the electric grid, more effort needs to be made on direct emissions from this sector. These emissions result from the combustion of fossil fuels for process energy (e.g., heating for furnaces, kilns, and dryers), chemical reactions that occur when raw materials are transformed into products (e.g., cement and ammonia), and the production and use of HFCs (see Box 6).[202]

Addressing manufacturing and industrial sector emissions will require new technologies beyond what exists today. It is particularly challenging to develop solutions for this sector due to the wide variety of activities involved. Energy efficiency; renewables; high-heat concentrated solar power; electrification; low-carbon hydrogen; advanced nuclear; and carbon capture, utilization, and sequestration technologies all hold promise. Successfully developing and deploying these types of technologies will reduce carbon pollution and increase the sector's competitiveness. Federal policy support that provides the right incentives and certainty will be essential for the development and commercialization of these technologies

Key Technology Focus Areas

Opportunities to innovate and secure manufacturing preeminence exist for various technologies across sectors. In the power sector, for instance, offshore wind is a huge untapped opportunity in the United States. Driven largely by state-level policy commitments, especially in the Northeast, the market is expected to grow from 5 turbines deployed today to at least 1,000 by 2030.[203] This presents nearly $70 billion in business opportunities in the U.S. offshore wind supply chain.[204] In response, some European wind turbine manufacturers as well as U.S. companies are beginning to locate R&D and production facilities in the United States.[205]

Energy efficiency products such as LED bulbs, high-efficiency appliances, and better motors are also a source of manufacturing strength for the United States. Manufacturing these energy efficiency products employed over 325,000 Americans in 2019.[206] The United States should continue to compete and advance manufacturing capacity in these technologies. The global market for energy efficiency products and services generated $298.5 billion in revenue in 2018 and is increasing rapidly as climate targets and government regulations continue to drive the adoption of efficient and intelligent building technologies.[207] The global demand for air-conditioning units is going to explode over the next three decades, further providing opportunities for American manufacturers of energy efficient air conditioners to tap into the market.

The manufacturing of advanced small modular reactors (SMRs) could represent yet another area of opportunity for the country if they become cost competitive with other low-carbon technologies. An SMR can provide nuclear power at a lower capital cost through mass factory production and thereby overcome the significant challenges facing current large nuclear construction projects.[208,209] Given their size and operational flexibility, SMRs can also have significant application in industries by substituting for fossil energy used for industrial heat processes, in addition to their use for power generation.[210] Of course, critical issues involving safety, nonproliferation, waste disposal, and potential impacts on local communities will have to be fully addressed. The path to wide-scale SMR deployment remains long, but supportive policies can enable faster progress. There are about two dozen SMR designs trying to break into the market, and the DOE has made it one of its top priorities to facilitate the development of these new technologies.[211] Currently, NuScale Power's SMR design has made the greatest progress towards Nuclear Regulatory Commission approval, and the company has signed memorandums with Canada, Jordan, and Romania for deploying its technology.[212]

Carbon capture, utilization, and storage (CCUS) presents yet another business opportunity for American manufacturers. The technology could potentially be used in industries with highly concentrated CO_2 emissions, such as natural gas processing and ammonia and ethanol production; industries that are harder to abate, including cement, iron, and steel manufacturing; and, finally, in power generation.[213] So far, CCUS technology has proved challenging for commercial deployment, and concerns persist about the feasibility of this technology and its economic viability. While fewer than 100 projects have been deployed globally, most of them are in the United States due to a combination of federally supported demonstration projects, the presence of a significant number of natural gas processing plants, and the demand for CO_2 in enhanced oil recovery.[214] The adoption of stable policies that encourage investment in long-term capital assets, including the current federal 45Q tax credit for CCUS projects, can significantly increase the number of applications and industries in which CCUS technology can be successfully deployed.

Low-carbon hydrogen has a wide variety of potential applications in industrial processes and heavy transportation (see Box 7). While low-carbon hydrogen is not yet widely used, governments have begun to invest heavily. China, Japan, and South Korea have set ambitious targets to develop and deploy hydrogen-powered vehicles by 2030.[215] In the United States, California has a target of 200 hydrogen fueling stations and over 47,000 hydrogen vehicles by 2025. Low-carbon hydrogen's greatest potential may be in the industrial sector. Many industrial processes need high temperatures, such as forging steel or firing cement kilns. Using electricity instead of fossil fuels to create this heat is a potential solution, but in many of these industrial applications, it is either not completely proven or is too costly. Low-carbon hydrogen combustion offers a promising alternative to obtain

Box 7 | The Basics of Hydrogen

There are three technologies to produce and deploy hydrogen (H_2). "Black H_2" is produced through steam reforming of natural gas or mineral oil, resulting in the release of carbon dioxide (CO_2) into the air. This is currently the most cost-effective and popular way of producing hydrogen. A cleaner version is "blue H_2," which is produced through steam reforming but with the capture of 80–90 percent of CO_2 produced. The CO_2 is then compressed, or liquified, before transporting and storing it. This technology is still in a relatively nascent stage. The cleanest is "green H_2," which is produced by using renewable energy to power water electrolysis, a process that generates zero carbon emissions. Blue H_2 increases the cost of producing hydrogen by 20–50 percent, but green H_2 currently represents a 200–400 percent increase over the cost of producing black H_2.[a] Green H_2 is, however, projected to be cost competitive in the coming decades if appropriate policies are put in place. The falling costs of electrolyzers and renewable generation can help lower its cost from the current $2.50 per kilogram (kg) to between $0.80/kg and $1.60/kg, making it competitive with gas in most parts of the world.[b]

a. Sandalow, D., J. Friedmann, R. Aines, C. McCormick, S. McCoy, and J. Stolaroff. 2019. *ICEF Industrial Heat Decarbonization Roadmap*. Tokyo: Innovation for Cool Earth Forum. https://www.icef-forum.org/pdf2019/roadmap/ICEF_Roadmap_201912.pdf.

b. BloombergNEF. 2020. *Hydrogen Economy Outlook: Key Messages*. New York: BloombergNEF. https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf.

high-temperature heat.[216] The United States can secure a share of the future global energy market—estimated to reach between $1 trillion and $2.5 trillion by the middle of this century[217,218]—by leading the development and commercialization of low-carbon hydrogen technology.

Finally, additive manufacturing, also referred to as 3D printing, offers huge potential to reduce energy use and cut waste and material costs in manufacturing processes.[219] Additive manufacturing techniques can be applied across the manufacturing sector, but they have strong energy savings potential for certain sectors, such as aviation and automotive, which rely on the complex use of materials and component parts.[220] Thanks to early investment by the DOE, the United States has built an early lead, and it is important to continue to support development of this technology domestically.[221]

Given the broadly shared concern about economic recovery in the country, this is an ideal moment to revitalize America's manufacturing sector by scaling up the production of low-carbon products, equipment, and technologies. Well-crafted strategies that focus on advancing the nation's low-carbon manufacturing prowess can accelerate job creation and economic growth. They also can bolster America's economic competitiveness at a time of rising economic pressures and high unemployment and simultaneously address the threats posed by climate change.

Reenergizing Rural America

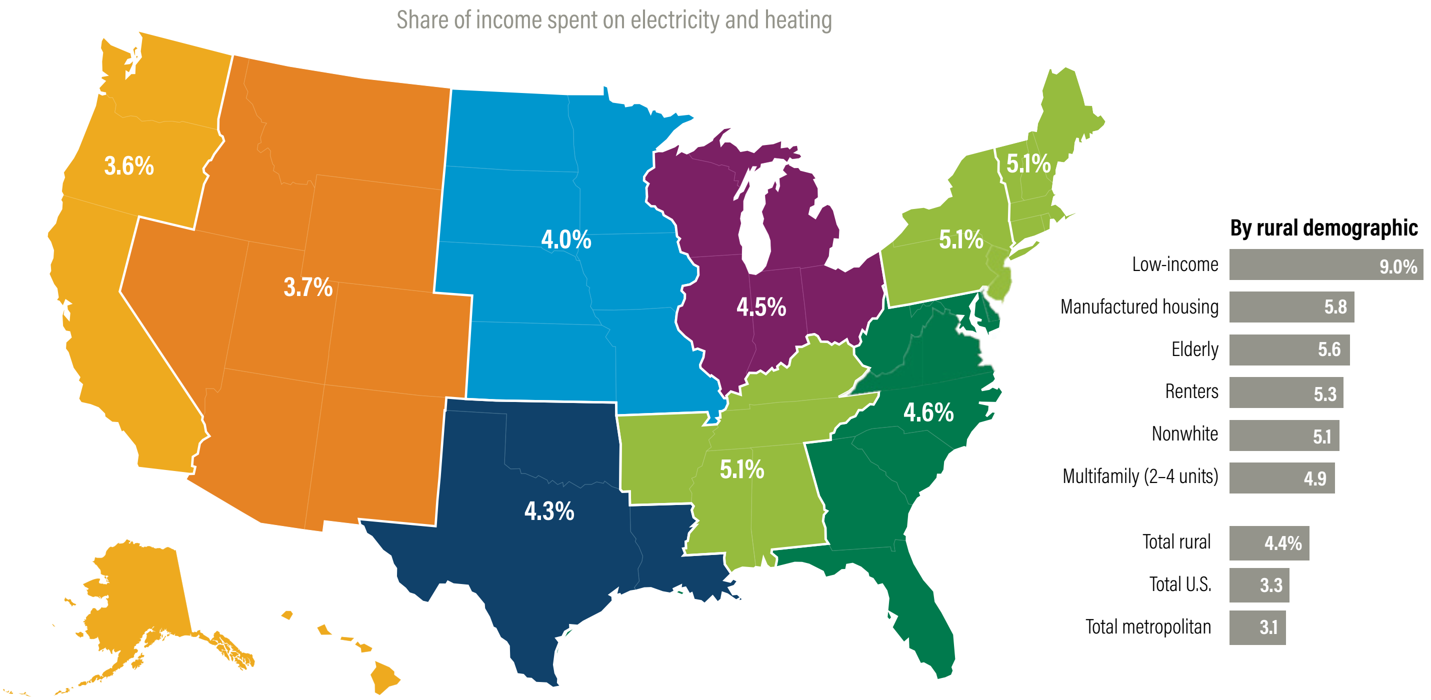
Climate change presents enormous challenges for rural America in addition to the economic headwinds that are already stymieing growth and widening the gap between rural and urban economies. Yet climate action can help reenergize America's rural and farming communities. The unique opportunities for rural America arise from its vast land resources, where wind and solar farms can be built on a large scale, transmission infrastructure can be upgraded and modernized, and carbon can be sequestered in agricultural lands and forests. Furthermore, clean energy can help address the high energy burden often experienced by rural households.

Lifting the Energy Burden of Rural Households

Households in rural areas across America often pay higher energy prices than those in urban areas. One study has estimated that rural households spend 40 percent more of their income on electricity and heating bills than urban households.[222] Low-income rural households face the highest energy burden, spending 9 percent of household income on energy bills compared to the national average of 3.3 percent (see Figure 22).[223] High energy costs can place a significant financial burden on rural households, even forcing them to make difficult trade-offs between paying energy bills and meeting other basic needs such as food or medicine.

Clean energy programs, including energy efficiency and renewable energy, can play an important role in lifting the high energy burdens of rural households. Retrofitting the median rural household to be more efficient per square foot (by adding insulation and sealing air leaks, for instance) would result in a 25 percent reduction in overall rural energy burdens.[224] This translates into more than

Figure 22 | **Rural Households Spend More of Their Income on Energy Bills**



Source: Ross, L., A. Drehobl, and B. Stickles. 2018. *The High Cost of Energy in Rural America: Household Energy Burdens and Opportunities for Energy Efficiency.* Washington, DC: American Council for an Energy-Efficient Economy. https://www.aceee.org/sites/default/files/publications/researchreports/u1806.pdf.

$475 in savings annually for rural households. In addition to cutting energy bill costs, energy efficiency upgrades can increase household health, quality of life, and property values.[225] Efficiency investments can also stimulate rural economies by creating local jobs.

Renewable energy can also lower energy costs for low-income rural residents. The location of many renewable energy resources near rural communities presents a unique opportunity for rural electricity providers. Distributed energy generation can eliminate the excessive costs of connecting long transmission lines from generation sites to individual rural communities that typically have a low customer base. The favorable economics of renewable energy is also pushing both cooperative electric utilities and investor-owned utilities in rural America to invest in renewable electricity generation (see Box 8).

Beneficial electrification—the replacement of fossil fuel–powered systems with electrical systems to reduce emissions—provides further opportunities to generate cost savings for rural communities (see Table 6).[226] While fuel oil and propane are the primary heat sources for 12 percent of U.S. homes nationally, the share is much higher in rural areas. Rural homes in the Northeast have some of the highest energy burdens in the country, in part because they rely on oil for heating. Replacing oil and propane furnaces, boilers, and water heaters with electric heat pumps can reduce both energy use and save money.[227] When such programs are paired with other energy efficiency measures, such as insulation and air sealing, rural households can further enhance the savings generated by the new electric equipment. The up-front cost of replacing oil- or propane-powered equipment can, in most cases, be recouped in a relatively short time.[228]

Finally, many technologies on American farms are promising candidates for end-use electrification, leading to reduced energy and maintenance costs as well as reduced noise and air pollution. A number of existing and emerging electric technologies have the potential for widespread adoption, ranging from radio wave grain dryers to electric tractors.[229] The most significant opportunity for GHG reduction exists with electrifying tractors and other farm vehicles, followed by space heating

Box 8 | Rural Electric Cooperatives Are Bringing Renewable Energy to Their Constituencies

Cooperative (co-op) electric utilities—consumer-owned utilities that predominantly serve rural and suburban areas—are emerging as important players for providing affordable renewable energy to rural residents. As nonprofits owned by their members, electric co-ops have a commitment to serve their members by providing safe, low-cost, and reliable power. Ninety-five percent of the nearly 900 co-ops represented by the National Rural Electric Cooperative Association generate or procure renewable energy in their communities. In 2014, electric co-ops collectively provided about 113 megawatts (MW) of solar capacity, with the average size of a co-op installation at 25 kilowatts. By 2017, the total capacity grew eight times to nearly 870 MW, and the average installation provided 1 MW. At the end of 2019, total solar capacity was projected to exceed 1 gigawatt, enough electricity to power 200,000 homes. Hawaii's Kauai Island Utility Cooperative meets more than 50 percent of its energy needs with renewables, up from 8 percent in 2010. The Farmers Electric Cooperative, serving 650 rural Iowans, generates more than 20 percent of its power from solar and has been recognized as among the top 10 utilities for utility green power programs. At the same time, many cash-strapped rural co-ops are struggling to participate in the clean energy transition due to billions of dollars tied up in uneconomic coal plants. Solving the coal debt problem will be key to enabling these rural co-ops to add on more renewable energy projects.

a. Jackson, L. 2019. "Energizing Rural America: A Cooperative Effort to Advance Renewable Power." Bipartisan Policy Center. August 8. https://bipartisanpolicy.org/blog/energizing-rural-america-a-cooperative-effort-to-advance-renewable-power/#:~:text=Energizing%20Rural%20America%3A%20A%20Cooperative%20Effort%20to%20Advance%20Renewable%20Power,-By%20Lexi%20Jackson&text=As%20renewable%20energy%20resources%20become,portfolio%20of%20the%20electric%20grid.

b. National Rural Electric Cooperative Association. 2018. *A Solar Revolution in Rural America*. Arlington, VA: National Rural Electric Cooperative Association. www.cooperative.com/programs-services/bts/sunda-solar/Documents/Solar-Revolution.pdf.

c. Kauai Island Utility Cooperative. n.d. "Renewables." https://website.kiuc.coop/renewables. Accessed June 1, 2020.

d. Rural Solar Stories. n.d. "Farmers Electric Cooperative: Iowa." http://ruralsolarstories.org/story/farmers-electric-cooperative/. Accessed June 1, 2020.

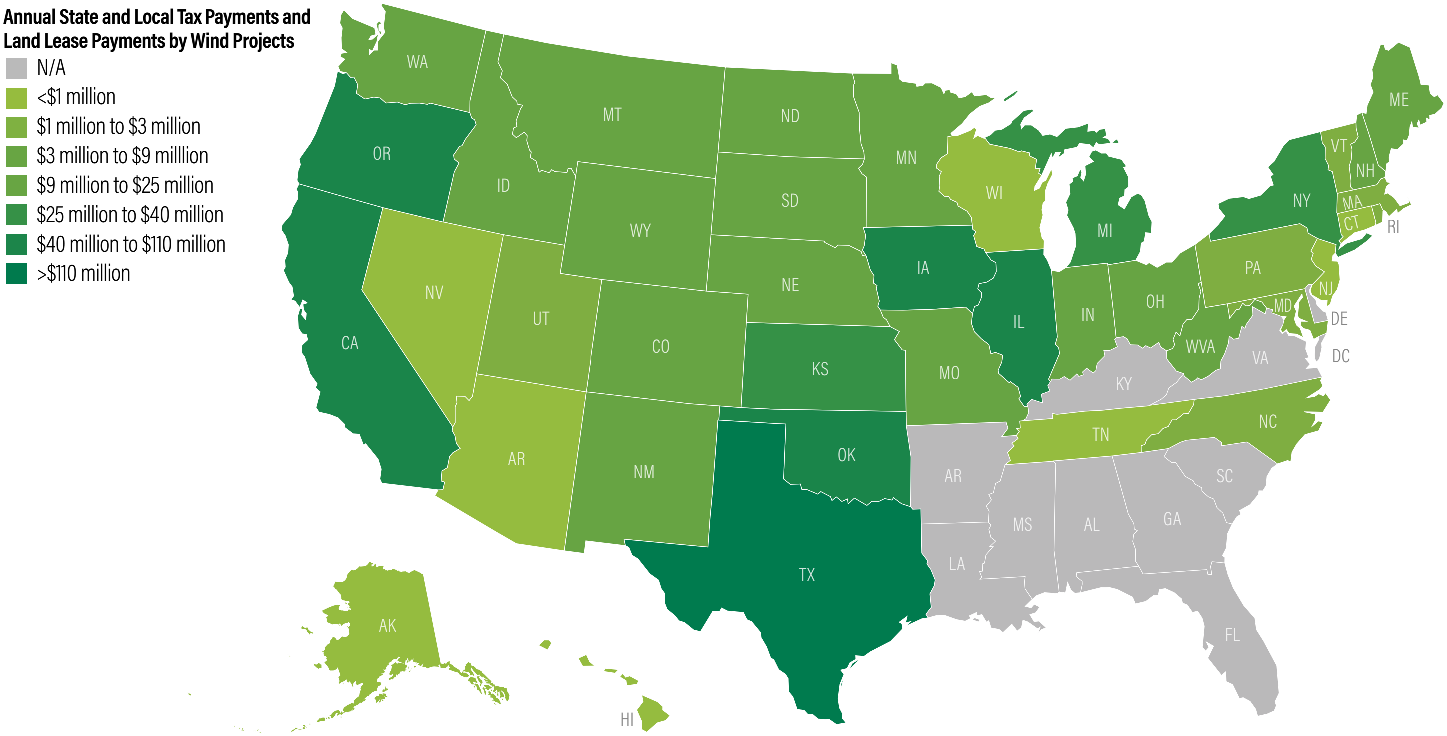
e. Hatlestad, E., K. Rock, and L. Veazey. 2019. *Rural Electrification 2.0: The Transition to a Clean Energy Economy*. Lyons, NE: Center for Rural Affairs; Montevideo, MN: CURE; Madison, WI: We Own It. https://www.cfra.org/sites/www.cfra.org/files/publications/Rural%20Electrification%202.0.pdf.

Table 6 | Studies of U.S. Energy System Net Costs on a Low-Carbon Pathway Compared to Reference Case

ELECTRIC TECHNOLOGY	PRIMARY FARM TYPES	COMMERCIALIZATION STATUS	AGRICULTURAL MARKET PENETRATION
Irrigation pumps	Orchards, vegetables, field crops	Available, widespread	High
Water heaters	Dairy	Available, widespread	Medium
Heat exchangers	Poultry, swine, greenhouse	Available, limited	Very low
Maple sap evaporators	Maple	Available, limited	Very low
Thermal electric storage systems	Poultry, swine, greenhouse	Available, limited	Very low
Radiant heaters	Poultry, swine, greenhouse	Early, limited	Very low
Heat pumps	Field crops	Early, limited	Very low
Grain dryers	All, especially field crops	Early, limited	Very low

Source: Clark, K. 2018. *Farm Beneficial Electrification: Opportunities and Strategies for Rural Electric Cooperatives.* Arlington, VA: National Rural Electric Cooperative Association. https://www.cooperative.com/programs-services/bts/Documents/TechSurveillance/Surveillance-Article-Farm-Beneficial-Electrification-October-2018.pdf.

Figure 23 | **Wind Energy Generated More than $1 Billion in Tax Revenue and Lease Payments to Landowners in 2018**



Source: American Wind Energy Association. n.d. "Wind Facts at a Glance." https://www.awea.org/wind-101/basics-of-wind-energy/wind-facts-at-a-glance. Accessed June 5, 2020.

in greenhouses and livestock barns and electrifying irrigation.[230] Currently, irrigation electrification—switching from diesel- and natural gas–fueled groundwater pumps to electric groundwater pumps—is the most common, whereas other technologies are further behind on the adoption and cost curves.[231]

Linking Clean Energy to Rural Economic Development

In the rural United States, renewable energy development offers an opportunity to create new sources of employment and tax revenues and to diversify rural economies.

DIVERSIFYING RURAL ECONOMIES

Wind energy is diversifying rural economies by adding to the tax base and providing new streams of income for farming and ranching communities (see Figure 23). According to the American Wind Energy Association, in 2018 wind farms paid $761 million in state and local taxes plus $289 million in lease payments to farmers and landowners who hosted wind turbines on their land.[232] For example, in Adair County, Iowa, 10 new wind farms built over the last decade have added 30 percent to the county's tax base.[233] In Jackson County, Minnesota—one of the most active counties for wind farm development in the state—wind farms generated 16 percent of the county's operating revenues in 2017.[234] These revenues are being channeled into school districts and community development projects, significantly impacting the quality and accessibility of public resources.

There is emerging interest in using solar energy to help farmers diversify their income.[235] Farmers can lease some of their land to solar developers who install panels and sell the power to local utilities. In North Carolina, for instance, solar developers offer farmers anywhere from $300 to $700 per acre, which is more than triple the average rent for crop and pasture land in the state.[236] This is a boon for struggling family farms that are contending with trade wars and floundering commodity prices.

While wind turbines do not take up very much space, there are concerns that renting acreage for solar panels will take land out of operation and could have serious consequences for food production.[237] Connecticut and Oregon, as well as counties in North Carolina and Washington State, have restricted solar development on prime agricultural land.[238] Yet other places are exploring the potential for solar to complement rural land uses, including solar plus grazing; solar plus crops, or agrivoltaics; and pollinator-friendly solar. Massachusetts's new solar incentive program, known as the Solar Massachusetts Renewable Target, offers extra compensation to farmers for agrivoltaic projects.[239] In addition, rural electric co-ops are pioneering innovative projects that integrate solar with other land uses.[240] Connexus Energy in Minnesota has developed a pollinator-friendly solar garden, and Indiana's Hoosier Energy has piloted a solar plus sheep grazing community solar project to benefit both the co-op and farmer.

DRIVING NEW INVESTMENT

The growth of low-carbon power across rural America is helping those places attract investment from companies looking to build data centers and other facilities that will run on clean energy.[241] Almost half of the Fortune 500 companies are planning to locate their operations in states with high levels of clean energy, including retail and tech companies with renewable energy commitments such as Amazon, Apple, Facebook, Google, Microsoft, Target, and Walmart.[242] These investments not only create local jobs but also provide significant tax revenue and infrastructure improvements to rural communities. An analysis of the economic impacts of typical data centers has found that they bring in millions of dollars in initial investment directly to local communities, which create ripple effects throughout the surrounding areas.[243]

Iowa has emerged as a leader in leveraging wind energy for economic development. It has a total wind capacity of over 8 GW and growing as well as the largest percentage of in-state generation from wind (37 percent). Apple, Facebook, Google, and Microsoft have made major investments in the state.[244] Apple's newest 400,000 square foot data center in Waukee, Iowa, will run entirely on renewable energy and is expected to create more than 550 construction and operation jobs. The company is contributing $100 million to a newly created public improvement fund dedicated to community development and infrastructure around Waukee.[245]

Rural communities also have opportunities to capitalize on the manufacture of components for renewable energy generation, such as wind turbines. Since each turbine contains over 8,000 parts, the wind industry has established an extensive global supply chain.[246] The U.S. footprint of that supply chain is spread across more than 500 U.S. factories—led by Ohio with 60 wind factories—that specialize in wind components such as blades, generators, and towers.[247] Many of these manufacturing facilities are already located in rural areas.

CREATING EMPLOYMENT OPPORTUNITIES

Although scant data exist on the impact of clean energy projects on employment in rural communities, one Natural Resources Defense Council study has quantified clean energy jobs related to renewable energy power generation, clean transportation, and energy efficiency across rural communities in 12 midwestern states (see Figure 24).[248] In 2017, clean energy employed 158,000 people in the rural Midwest, with most jobs in energy efficiency. Renewable energy was responsible for 17,000 jobs. Despite the small share, renewable energy jobs are important for counties where there are otherwise limited employment opportunities and employment growth has been slow.

The same study highlighted two reasons why these jobs are so consequential for rural America. First, clean energy jobs make up a higher percentage of total employment in rural areas than in urban areas. Second, while most of the rural Midwest experienced minimal or negative job growth from 2015 to 2016, clean energy jobs were booming.[249]

Enhancing Carbon Capture in Trees and Agricultural Soils

Natural carbon capture in trees and agricultural soils can enhance productivity, profitability, and resilience in U.S. farms, forests, and rural communities.[250] Tree restoration, whether in forests or interspersed across nonforested rural (as well as urban and suburban) landscapes, has the greatest potential to sequester carbon.[251] Improved soil management can also enhance carbon storage in agricultural soils by reducing carbon losses or increasing carbon uptake.[252] Soil management practices also provide other benefits, including reduced erosion, resilience to drought, and, in some cases, increased yields, which can translate to $30 or more per acre in annual net benefits for farmers over the long term.[253] This can open up a significant opportunity for farming communities to economically benefit from adopting improved soil management practices.

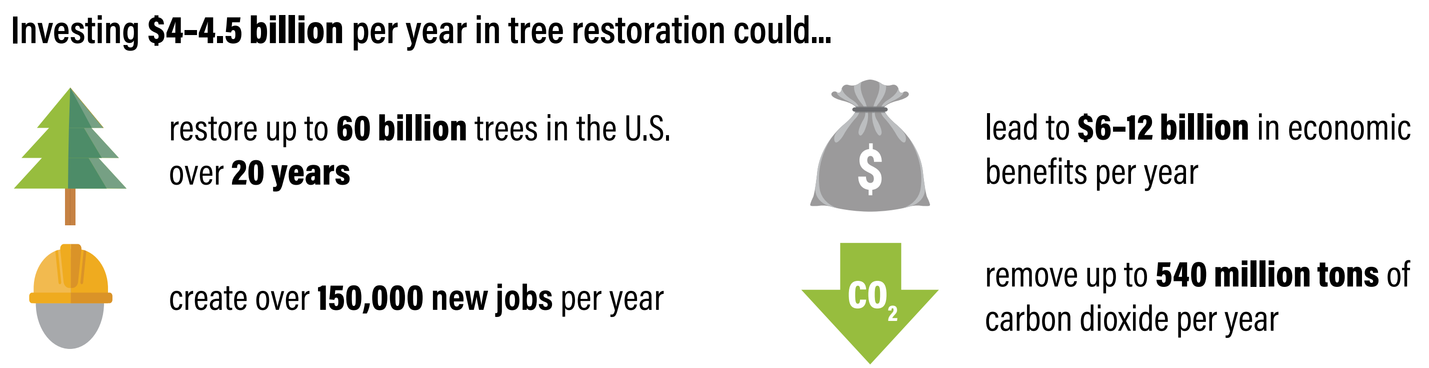
RESTORING TREES TO THE LANDSCAPE

According to a recent World Resources Institute study, restoring trees to the landscape represents the single largest near-term opportunity to deploy carbon removal at scale in the United States.[254] Tree restoration encompasses reforestation, restocking degraded forests, silvopasture, cropland agroforestry, and urban reforestation. Even though tree restoration potential is constrained by competing land-use demands, the study estimated that

Figure 24 | **The Impact of Clean Energy Jobs in the Rural Midwest**

Source: Krishnaswami, A., and E. Mittelman. 2018. *Clean Energy Sweeps across Rural America*. New York: Natural Resources Defense Council. https://www.nrdc.org/sites/default/files/rural-clean-energy-report.pdf.

Figure 25 | **The Economic Benefits of Investing in Tree Restoration**



Source: Rudee, A. 2020. "Want to Help the US Economy? Rethink the Trillion Trees Act." *Insights* (blog), World Resources Institute. April 6. https://www.wri.org/blog/2020/04/coronavirus-US-economic-recovery-tree-planting.

restoring trees to the American landscape could remove up to 540 megatons (Mt) of CO_2 per year through 2050 without displacing agricultural production.

In addition to carbon removal, tree restoration provides other economic benefits (see Figure 25). One study has found that every $1 million invested in reforestation and sustainable forest management has the potential to support 40 full-time-equivalent jobs.[255] An annual federal investment of $4–$4.5 billion in tree restoration can thus create over 150,000 new jobs, three times as many jobs as logging currently supports in the country. It would also generate $6–$12 billion per year in economic activity. Other benefits, such as building soil health, improving water quality, creating recreational opportunities, and, in some cases, providing farmers with additional revenue streams through agroforestry projects, help promote the well-being of rural communities.

Given the size of the opportunity for carbon removal from tree restoration and the many economic benefits associated with it, concerted action by the federal government is imperative to realize its full potential.[256] The significant up-front planting costs and lack of near-term financial returns from monetizable cobenefits makes tree restoration financially unfeasible for many landowners. This makes financial incentives critical to achieving the socially optimal level of tree restoration in the United States.

BUILDING SOIL HEALTH

Building soil health in the nation's farms and ranches can increase farm profitability and resilience while sequestering carbon. Key soil management practices include cover cropping, conservation tillage, crop rotations, compost amendments, grassland restoration, adding legumes to pasture, and grazing optimization. Many soil management practices are consistent with improved soil fertility, reduced soil erosion, reduced nutrient leaching, and often improved farm yields. A synthesis of the scientific literature found that agricultural soil management practices could remove up to 200 $MtCO_2$ per year by 2050 in the United States, though this estimate is subject to considerable uncertainty due to variability in the efficacy of soil management practices, uncertainty around the deep-soil carbon impacts of some practices, and other challenges to wide-scale implementation.[257]

As the idea of soil carbon sequestration takes hold, a number of policy solutions are emerging at the state level that aim to incentivize farmers by paying them to implement regenerative practices that reduce or remove carbon from the atmosphere.[258] In California, a portion of the revenue generated through the state's cap-and-trade program is dedicated to the Healthy Soils Initiative, which provides grants of up to $50,000 each to approximately 50 farmers to engage in sustainable practices, such as planting cover crops, introducing natural windbreaks, and creating silvopasture.[259] Maryland's Healthy Soils Program offers incentives and assistance to farmers to adopt practices that promote soil health and reduce harmful agricultural runoff into Chesapeake Bay.[260]

The examples cited above are important, but federal involvement can help transition agriculture towards carbon neutrality and support rural livelihoods on a national scale. The latest farm bill (the Agriculture Improvement Act of 2018) introduced a new program, the Soil Health Demonstration Trial, to measure and monitor soil health improvements and pay farmers for their work to sequester carbon.[261] Although a step in the right direction, larger-scale federal programs are still needed to harness the vast potential of American farmland to serve as carbon sinks. As an initial step, a federal program at the scale of $500 million annually over a 10-year period could spark innovation in agricultural soil management while collecting robust data across the landscape to understand which practices are most effective for yield improvements and carbon dioxide removal.[262] The program would provide financial support for practice implementation, technical assistance, and research and monitoring efforts across 10 million acres.

Rural communities, which are often on the front lines of climate change, are also key to effectively responding to this challenge. Policymakers will not only need to address the energy inequities dividing rural and urban areas but also ensure that rural communities are able to reap economic benefits by participating in the new climate economy.

5. ENSURING A FAIR AND EQUITABLE TRANSITION FOR ALL

The concept of a fair and equitable transition has emerged as a crucial element of U.S. (and global) climate strategy. The COVID-19 pandemic has exposed the long-running issues of energy inequality and the elevated risks of disease and death for low-income people living in polluted neighborhoods, further highlighting the importance of centering equity and social justice in climate policies. The transition to a new climate economy should be fair and equitable, including for the workers and communities whose livelihoods and well-being are closely tied to a high-carbon economy. It also should ensure that the benefits of decarbonization and climate policies reach every segment of society, especially low-income and pollution-burdened communities.

Incorporating equity into decarbonization strategies is not only the right thing to do but is also critical for the success and long-term effectiveness of the U.S. climate policy. Without a strong social dimension, it will be difficult to have buy-in from different groups for various decarbonization strategies. For example, fossil fuel workers facing job losses are more likely to support climate policies if those are accompanied by a secure pathway to a new, quality job and generous transition support that includes income and retraining assistance. Similarly, policies that make the benefits of transportation electrification accessible to low-income households, through targeted EV incentives, the availability of low-cost car-sharing programs, and electric transit buses, will generate more support for those policies in general.

The low-carbon transition will be disruptive for some workers and communities, regardless of the overall shared benefits of a low-carbon economy. If managed well, the transition to a low-carbon economy can help reduce the human, social, and economic costs of disruption from various climate policies.[263] It can also create new jobs and opportunities in America's new climate economy while producing sustainable and inclusive growth into the future. If poorly managed, U.S. decarbonization strategies will lead to stranded workers, communities, and assets, slowing the transition and contributing to instability.[264]

Helping to Transition Workers and Communities from Carbon-Intensive Industries

Although moving to a new climate economy will have net employment benefits economy-wide (see Section 3, Section 1), it will be more challenging for the many American workers and communities that have historically depended on jobs in various carbon-intensive industries, including oil, gas, and coal.

Many of the changes in the U.S. energy system are being driven by long-term market forces. The COVID-19 crisis is further amplifying them. The historic slide in oil prices due to pandemic-inflicted declines in demand is costing the oil industry thousands of jobs and is impacting the budget of states that rely on oil severance taxes. It also raises the question of how oil workers and communities that depend on the oil industry can be shielded from boom and bust cycles caused by market volatility and long-term economic disruptions when the climate crisis forces a transition away from fossil fuels. U.S. coal mining employment has fallen 42 percent since 2011, most significantly in the Appalachian region. This is because competition from natural gas and renewable energy sources for electric power generation has contributed to a drop in the demand for coal.[265] The COVID-19 outbreak is further accelerating the decline of the coal industry because utilities have turned to low-cost renewables and natural gas at a time of lower electricity demand. Similarly, the shift to EVs can have disruptive implications for American workers employed in the auto industry.

Given that EV power trains are mechanically simpler than ICE power trains, there are concerns that this could lead to thousands of job losses associated with vehicle production.[266]

Broader economic trends further complicate the transition pathway for these workers. Climate change is but one of the profound changes that is reshaping economies. Artificial intelligence, automation, and other technological changes are already disrupting the nature of work and are set to intensify in the coming decades.[267] A key reason why employment in the coal industry has fallen over the past several decades is automation, meaning fewer jobs per ton of coal produced.[268] The inevitable interaction of the low-carbon transition with technology-driven and various other changes including globalization, financialization, and reduction in power of trade unions could increase job impacts and shifts in the labor market.[269]

Whatever the cause, there will be acute implications for specific sectors and regions of the U.S. economy. These workers and communities will face significant economic disruption. When any large mine, plant, or factory closes, it has a ripple effect across the local economy. The impacts include not only lost jobs but also declining property values, reduced economic activity (partly via multiplier effects), and lost tax revenues for a town—leaving less money for infrastructure maintenance and the provision of local services.[270]

The low-carbon economy can provide opportunities for some of those currently employed in fossil fuel industries. As mentioned earlier, the clean energy industry has become a major U.S. employer, creating opportunities for workers in some of the country's most fossil fuel–heavy states. For instance, the solar and wind industries employ about four times as many people in electricity generation compared to the coal industry. Other jobs in carbon-intensive industries can be partially substituted through shifts to a low-carbon economy, such as from ICE manufacturing to EV production, or from landfilling to recycling.[271] In some cases, there could almost be a seamless transition of skills because the technical and managerial needs of the clean energy industry align with those in traditional energy industries. For example, engineers and geoscientists could switch from offshore oil drilling to offshore wind or from the oil and gas industry to the geothermal industry. Even unskilled workers employed in mining and oil and gas production can have a straight path to jobs focusing on decommissioning of fossil fuel infrastructure and environmental remediation.[272]

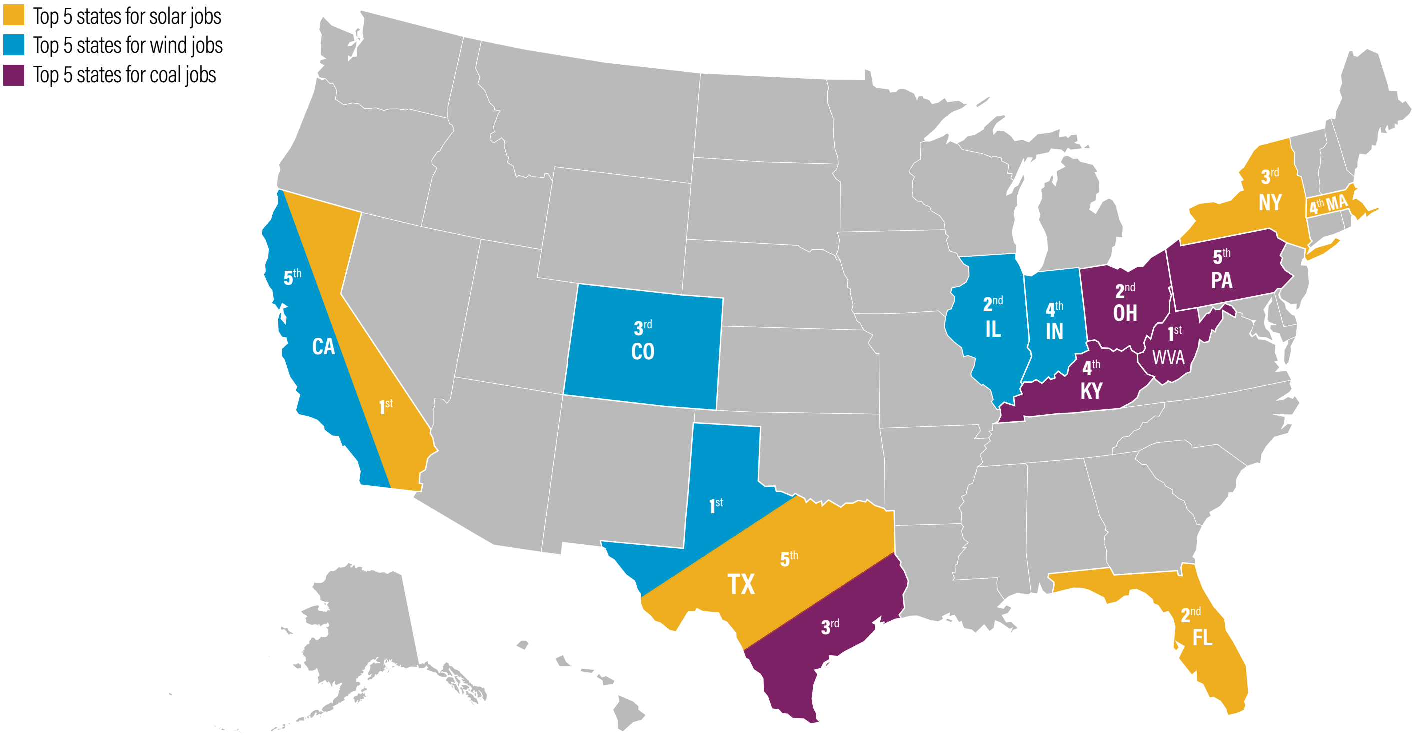
Carbon capture provides further opportunities for enabling a fair and equitable transition for fossil fuel workers. In many cases, though, modest public investment will have to made in reskilling workers in carbon-intensive industries to take up jobs in low-carbon industries. One study has estimated that $600 million per year over 20 years can pay for income, retraining, and relocation support for fossil fuel workers, in addition to guaranteeing the pension for workers in impacted industries and implementing transition programs in fossil fuel-dependent communities.[273]

A few words of caution are warranted, though. First, low-carbon jobs cannot directly replace every job lost in carbon-intensive industries due to a mismatch in skills, geography, and timing. It will be especially challenging for low-skilled older workers, who may find it difficult to upskill to compete for new jobs. This means that it will be important to provide opportunities for workers in all areas of the economy, not just in low-carbon areas, and to support older workers in particular, including by offering early retirement packages if they are near the end of their career.

Second, jobs in carbon-intensive industries are often geographically concentrated around a particular site, like a coal mine or an oil field. This means that a small number of states depend heavily on them. For example, in West Virginia and Wyoming, coal jobs make up more than 2 percent of all state employment.[274] Often, these regions are not in the vanguard of those creating new jobs in clean energy, which creates a geographic mismatch (Figure 26).[275] Recent trends in mobility are not encouraging either, with fewer Americans moving for work than ever before.

Finally, even though workers in clean energy are expected to earn more than the average U.S. workers, concerns about wages and job quality remain, especially in comparison to the fossil fuel industry.[276] Many workers in fossil fuels earn more than workers in renewable energy, and the rate of union representation among the former is higher too. Straight-up comparisons of job quality between fossil fuel and clean energy industries are complicated. In general, though, in moving towards nonunionized workplaces, fossil fuel workers could face jobs that are less secure, lower paid, and come with fewer benefits.

Figure 26 | **Coal and Renewable Energy Jobs Are Located in Different Parts of the Country**



Source: National Association of State Energy Officials and Energy Futures Initiative. 2020. The 2020 U.S. Energy and Employment Report. Arlington, VA: National Association of State Energy Officials; Washington, DC: Energy Futures Initiative. https://www.usenergyjobs.org/s/USEER-2020-0517.pdf.

All of these challenges make the delivery of a fair and equitable transition very complicated. Policy interventions to ensure a fair transition can, however, make a big difference. While there is no universal blueprint for implementing a fair transition, policy solutions should include certain core elements:[277,278,279,280]

- Anticipating changes and proactively planning for them.
- Including all relevant stakeholders in the conversation early on, across impacted communities, government, industry, and unions.
- Focusing on job creation and quality with adequate social protection for workers.
- Mobilizing the capital required from the public and private sectors to address both immediate needs, such as wage replacement or replacing lost tax revenue when a plant shuts down, and long-term needs, such as funding training and retraining programs, as well as seeding new business development.
- Investing in the human and social capital needed to underpin the transition.
- Focusing on economic diversification strategies and moving away from reliance on a single industry.

The U.S. government has a mixed history with helping workers in transitional industries. For example, the U.S. Trade Adjustment Assistance program was intended to assist workers impacted by globalization and trade, but success was limited. Less than half of the eligible workers received benefits from 1974 to 2013, and a substantial number of people who lost jobs due to automation were not eligible for support.[281] A more successful example is the Worker and Community Transition program from 1994 to 2004. It was operated by the DOE and supported 13 rural communities with high levels of job losses due to nuclear decommissioning; it helped workers find new employment and provided basic benefits for a transition period.[282]

Box 9 | How Securitization Can Help with a Fair Transition of Fossil Workers and Communities

Policymakers across the nation are grappling with how to retire uneconomic fossil fuel power plants while reducing the negative impacts on workers, communities, and ratepayers. Securitization is being explored in some communities to address the stranded asset problem, and some of the savings generated from the bonding transaction are reserved to help workers and communities. Securitization is similar to refinancing a home to take advantage of lower interest rates. A utility operating an uneconomic power plant is able to repackage its debt as bonds backed by a ratepayer guarantee. This leads to a significantly lower interest rate, typically around 3–4 percent, compared to 7–8 percent for conventional debt.[a] The savings can make it easier for a utility to shut down a plant sooner. Twenty states have legislation to enable securitization; in the past, utilities have successfully used it for a variety of needs. Duke Energy Florida, for instance, issued ratepayer-backed bonds a few years ago to retire a nuclear plant damaged by repair work.b The only difference is that now a strong case is being made to share a portion of the savings with the workers and communities affected by the plant's closure and the loss of jobs and tax base.

a. Uhlenhuth, K. 2019. "Kansas, Missouri among Latest States to Debate Refinancing for Aging Coal Plants." *Energy News Network*, May 1. https://energynews.us/2019/05/01/midwest/kansas-missouri-among-latest-states-to-debate-refinancing-for-aging-coal-plants/.

b. *Tampa Bay Times*. 2016. "Duke Energy Florida Customers Will See a New Charge on Their Bill Starting in July." June 16. https://www.tampabay.com/news/business/energy/duke-energy-florida-customers-will-see-a-new-charge-on-their-bill-starting/2282006/.

There have already been some federal efforts to aid fossil fuel communities. In states like Kentucky, Pennsylvania, and West Virginia, the Appalachian Regional Commission has invested over $190 million in 326 coal-impacted communities through the congressionally funded POWER initiative. Together, these investments in manufacturing, technology, substance abuse recovery, and other industry sectors are projected to create or retain more than 23,000 jobs and leverage more than $811 million in additional private investment into Appalachia's economy.[283]

Previous federal programs can serve as useful models on how to support workers and communities in carbon-intensive industries facing transition. However, more robust federal policies and programs are required to help these workers and communities. This imperative extends far beyond the workers employed in the coal industry and has to include oil and gas workers, those who may face dislocation due to a transition to EVs, and other workers likely to be adversely impacted by the low-carbon transition.

A range of solutions are beginning to be implemented at the subnational level. Colorado created the Just Transition Office, which is the first of its kind. The office is charged with creating an equitable plan for coal-dependent communities and workers, and it has a dedicated staff and an advisory committee of diverse stakeholders.[284] In New York, $45 million in "gap funding" is available to help replace the taxes that a closed power plant would have paid.[285] Finally, Colorado, Montana, and New Mexico are looking at securitization—giving coal-owning utilities the option to issue bonds secured by the certainty of customers paying their bills—as a tool to pay off stranded coal assets and provide transition funds to affected communities (Box 9).[286] The federal government can help amplify these efforts through infrastructure investments and tax credits and by repurposing old energy sites for other economic uses, to name just a few policy options.

Ensuring the Benefits of Climate Policies Are Shared by All

A second priority for policymakers is to ensure that decarbonization policies do not unduly harm low-income and disadvantaged households and communities and that the benefits of low-carbon technologies are available to all. For example, even as EV deployment has increased in recent years, there are barriers for low-income drivers.[287] They are often unable to take advantage of federal tax credits incentivizing EV adoption, and they are more likely to live in multiunit dwellings whose building codes have not been updated to accommodate EV charging spaces.[288] Similar disparities are being seen in the deployment of rooftop solar PV panels, which are predominantly installed in white neighborhoods, even after controlling for household income and home ownership.[289] These examples highlight that while low-carbon technologies can be powerful tools for addressing climate change, a lack of access can dramatically weaken their social benefits and fracture coalitions.

In contrast, well-designed climate policies present an opportunity to remedy existing injustices in the current energy system. For instance, a significant body of literature has shown that economically disadvantaged and minority communities experience higher levels of toxic pollution from the burning of fossil fuels. Initial evidence also seems to suggest that people exposed to air pollution are at greater risk of becoming ill or dying from COVID-19.[290] Regulations addressing air pollution and a transition towards clean energy can therefore alleviate health crises that disproportionately impact low-income and minority communities. Unfortunately, the recent decision by the Trump administration to weaken the regulations requiring power plants to reduce emissions of mercury and other air pollutants is a step backwards.[291]

Similarly, low-income and minority households, particularly in rural areas, have struggled with energy and transportation access over the years.[292] In the United States, nearly 25 million households face hard choices between paying their utility bills and purchasing other necessities such as health care and food.[293] In 2015, 14 million households had unpaid utility bills, 17 million had received a disconnection notice, and 2 million were disconnected from the electric grid.[294] The COVID-19 pandemic is further highlighting the long-running issue of energy inequality, with threats of utility disconnections and unpaid energy bills looming for many low-income households. And despite the latest innovations in transportation, including EVs and ride sharing, low-income households who stand to gain the most from expanded transportation options are also the most likely to be excluded from them. Increasingly impacted by climate change, these communities also have the fewest resources to prepare for and recover from extreme weather events.[295]

Climate policies offer an opportunity to increase the inclusivity of the energy economy. While the fossil fuel industry has typically been less diverse, the current roster of workers in the clean energy industry is also far from inclusive: the clean energy workforce predominantly comprises older male workers and lacks racial diversity in comparison to all occupations nationally.[296] Unless equity is made a priority, the inequality of the carbon-based economy will be replicated as America builds a new climate economy.

Low-income and disadvantaged communities are not going to automatically reap the benefits of climate policies. Policies to address climate change should be designed in ways that bring everyone into the new climate economy. These policies have to be tailored to each community, guided by local knowledge, and informed by all relevant stakeholders. An inclusive low-carbon transition is a collective good. It must be driven by significant public investment to decarbonize key sectors of the economy while ensuring that those resources are sufficiently targeted towards low-income and marginalized communities so they can enjoy the benefits of the new climate economy.

In response, some state and local governments are rising to the challenge. The money from California's cap-and-trade program is used for a variety of clean energy projects and, by law, at least 35 percent of the funding is used to benefit disadvantaged and low-income communities and households.[297] In Fresno, California, a $7 million program, funded by cap-and-trade proceeds, is deploying a fleet of EVs as a van pool for under-served areas.[298] Several states and the District of Columbia have adopted policies to increase low- and moderate-income (LMI) access in community solar programs. These range from mandating community solar with a certain percentage of LMI customers (for example, Colorado, Connecticut, Maryland, and Oregon) to providing incentives (Illinois, Massachusetts, Rhode Island, and Washington, DC).[299] City and state governments are also developing new programs to expand the deployment of EVs beyond early adopters to low-income buyers and residents of multiunit dwellings.[300] A number of transit agencies offer discounted fares for low-income riders, and some cities, such as Chicago and Los Angeles, are exploring the expansion of car- and bike-sharing programs to low-income communities.

These are good initial steps, but much more work will be needed to ensure that an equitable climate policy is viewed as an essential element rather than as an afterthought in climate conversations.[301] Doing so will require a range of policies that consider economic inequality, including targeted subsidies for EVs, funding to expand public transit in high-capacity routes and to adopt clean energy technologies in under-served communities, and agreements that enable communities hosting clean energy projects to receive a share of the project's benefits.[302]

CONCLUSION

As the United States begins its recovery from the health and economic impacts of the COVID-19 crisis, it is imperative that the country begins to prepare for the next big global challenge. The pandemic has exposed the danger of failing to plan ahead, and the nation can ill afford to forget the lesson. Climate change presents serious risks to the U.S. economy and its ecosystems, and it demands an urgent response from policymakers at all levels of government. American energy systems, transportation, industry, and land use will have to change at a fast pace and a massive scale, but a new climate economy is not impossible to attain.

As this paper shows, the United States stands to benefit economically from taking strong climate action. Deep decarbonization of the U.S. economy must be viewed as an investment in the country's future, which presents not just long-term benefits but also immediate, near-term opportunities. If the investment is made wisely, it will generate a wide range of opportunities for growth, development, and inclusion along the way.

In the near term, policymakers should ensure that they are safeguarding policies and regulations that enable the low-carbon transition, standing firm against pushback on regulatory structures, and making adjustments to energy policies to aid the clean energy industry. The fossil fuel industry is already using the COVID-19 crisis to get the federal government to roll back regulations that it finds objectionable. While temporary relief for workers in the fossil fuel industry can be justified to ease the burden during a time of crisis, permanent subsidies or regulatory reversals will be dangerous to the long-term environmental health of the country. Furthermore, modifications to existing energy policies, such as granting additional time to renewable energy projects to finish construction in order to access federal tax credits, can provide a much-needed lifeline to the renewable energy industry.

In the medium-term horizon, the United States must implement strategies that can sustain the transition to a new climate economy. Anticipated stimulus and recovery packages provide a valuable opportunity to direct federal resources towards a buildup of low-carbon infrastructure that can create jobs and stimulate economic activity. In the months ahead, the economic recovery process offers the chance to undertake energy efficiency building upgrades, roll out multigigawatt utility-scale solar and onshore and offshore wind projects at low costs, build high-voltage direct current transmission lines than can bring renewable energy from distant locations to major population centers, and modernize and electrify the nation's public transportation system, among other things.

Over the long-term horizon, the United States will need bold, visionary policies to steer the country on a path that leads to carbon neutrality by 2050. During the last decade, U.S. states, cities, and private actors have emerged as leaders of the U.S. response to climate change. They will have to keep up their momentum and even ratchet up their climate ambition, and the federal government will need to reengage to create durable, uniform policies and regulations for the entire country. Options on the table include some version of carbon pricing, national clean electricity standards, and a reinvigorated focus on R&D and the demonstration of clean technologies to enable the decarbonization of all sectors of the U.S. economy. How each of these policies can be put into action remains an area of discussion, but the decarbonization challenge requires that policymakers start thinking about their design immediately.

The United States stands at a historical crossroads. If it acts now, America can look forward to a future that is pollution free, healthier, inclusive, and prosperous. By 2050, millions of Americans would be employed in the new climate economy, receiving competitive wages while producing goods and services with an environmental benefit. American businesses would be exporting innovative low-carbon technologies to the rest of the world. The United States would be generating abundant, cheap electricity from renewable energy and other clean sources. Communities, especially those that have historically suffered from pollution, would breathe clean air. American consumers, including those in rural areas, would save on energy costs with affordable low-carbon technologies. New buildings and cars would be all electric. Farmers would be rewarded for practices that capture carbon.

For people, the planet, and the economy, the transition to a new climate economy might be the best bargain of our time.

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ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

ABOUT NCE

The Global Commission on the Economy and Climate and its flagship project, the New Climate Economy (NCE), were set up to help governments, businesses, and society make better-informed decisions on how to achieve economic prosperity and development while also addressing climate change. The project has released major flagship reports as well as country reports on Brazil, China, Ethiopia, India, Indonesia, Uganda, and the United States, as well as various working papers on cities, land use, energy, industry, and finance. The project's reports and outreach seek to reframe the global debate about effective economic and climate policy, making the case for actions that can deliver both economic growth and address climate risks. It has disseminated its messages by engaging with heads of governments, finance ministers, business leaders, and other key economic decision-makers in over 60 countries around the world. Additionally, the project works closely with in-country partners to translate the NCE narrative into a cross-economy approach, tailored to specific country circumstances, to identify opportunities to align sectoral agendas into practical implementation plans to meet strengthened climate and development goals.

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