THE CASE FOR CLIMATE ACTION

BUILDING A CLEAN ECONOMY FOR THE AMERICAN PEOPLE

AUGUST 25, 2020

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Senate Democrats'
SPECIAL COMMITTEE ON THE
CLIMATE CRISIS

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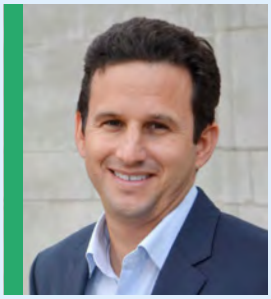

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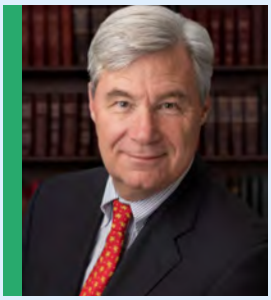

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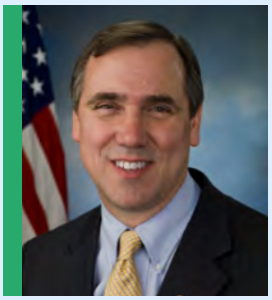

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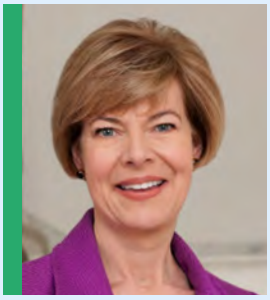

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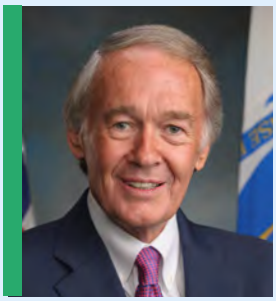

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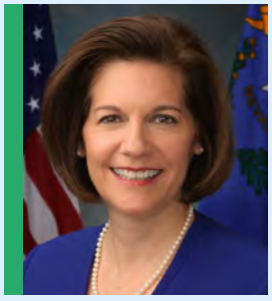

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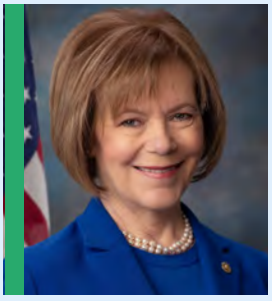

Tina Smith
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INTRODUCTION

The climate crisis threatens our lives and livelihoods. The evidence is clear: we must flatten the warming curve, and fast. The Intergovernmental Panel on Climate Change (IPCC),[1,2] the U.S. National Climate Assessment,[3,4] and other reports give us the scientific imperative for action. It is scary stuff. But too much of the climate movement of the past was about what climate change *is doing to us*, and not about what climate action *will do for us*. Taking action does not require austerity and scarcity. Done well, it will result in more wealth, more fairness, better jobs, and more security for every American. We already have the technologies needed to avert catastrophe. We just need the American optimism and the political will to deploy them on an unprecedented scale. To ignite this transition, we need Congress to act. This report provides a framework for Congress to finally do what is necessary to build the clean energy future we all deserve.

Too much of the climate movement of the past was about what climate change is doing to us, and not about what climate action will do for us. Taking action does not require austerity and scarcity. Done well, it will result in more wealth, more fairness, better jobs, and more security for every American.

Choosing action means choosing American wealth and American leadership. Individually, we will benefit from better technology, cheaper energy, and things that simply work better. The transition will make our economy stronger, drive innovation, and create millions of new careers that cannot be outsourced overseas. It will also ensure that America is not left behind as other countries develop the technologies of tomorrow.

What we are describing is a future with an improved quality of life, more fairness, and better products. Cars will be better—safer, cleaner, quieter, and you will never need an oil change. Indoor air quality will improve. Windows will be solar panels so that whole skyscrapers, and not just roofs, generate clean electricity.[5] The materials used to build homes and office buildings will store carbon instead of being a significant source of carbon pollution.[6,7] By powering American homes with clean energy, electricity prices will be more affordable and more stable. Clean energy is already cheaper in many instances, and prices continue to drop fast.[8]

Our neighborhoods will become healthier and more livable. Cleaner air will mean thousands fewer deaths and millions fewer children suffering from asthma.[9,10] The power will stay on during severe weather events because of more resilient electric grids. Green infrastructure will better protect homes and communities from flood waters.[11] More trees and green spaces will make the places where we live more appealing and summer temperatures more bearable. Farming and rural economies will benefit from new sources of income and investment, as well as greater protection from extreme wildfires, droughts, and other growing threats. If we do this right, the people and communities that have been treated unfairly, exposed to chronic pollution, and left out of economic progress in the past stand to gain the most in the transition.

And finally, after 50 years of talking about it, we can achieve true energy independence. The oil price war earlier this year made clear that U.S. oil remains captive to the ups and downs of global markets and foreign powers. Nothing could be further from "independence" than leaving American workers and consumers constantly exposed to other nations' whims.

ACHIEVING A CLEAN ECONOMY WILL CREATE MILLIONS OF NEW JOBS in our country and positively impact household income.[12] In the recent past, renewable energy jobs have grown fast. Wind and solar jobs have been the two fastest growing professions in the nation in the last 10 years, with roughly 60 percent growth rates.[13] Studies estimate that every $1 million shifted from fossil fuel-generated power to clean energy creates a net increase of five jobs.[14]

American leadership in manufacturing was once the foundation of a large middle class, and it can be again if we focus on clean technologies. Building electric cars, wind turbines, and energy efficient appliances in the United States will generate millions of new jobs.[15] Making the components of clean products here at home, such as batteries and low-emission cement and steel, will amplify these jobs numbers many times over. Targeted investments to develop the full supply chains for these products will put Americans to work. Outcomes of R&D investments will also create new products, new materials, and new technologies, all of which can be made domestically.[16,17]

Job creation will not be limited to manufacturing. Constructing and retrofitting resilient and energy efficient buildings and public infrastructure will also require huge numbers of skilled workers. In rural America, climate-smart agricultural practices can help sustain and grow farm jobs and agricultural economies. Incentives and carbon markets can pay farmers and ranchers to sequester more carbon in soil—making them more productive and more resilient to a changing climate.[18,19] This money can diversify farm income and smooth the volatility in traditional commodity prices.

There is a closing window not just to hold global temperature increase below catastrophic levels, but also for the United States to create these new jobs domestically and ensure they are good-paying jobs. If we do not choose to act soon, these industries will be dominated by other countries and the jobs will be created overseas. We must not miss our opportunity to again lead global economic development for the next century.

HOW, SPECIFICALLY, DO WE ACHIEVE THIS CLEAN ENERGY FUTURE?

It is time to decarbonize everything possible: our cars, our homes, our public transportation, and our office buildings. In the near term, we must continue to significantly grow solar and wind energy, energy storage, and electric vehicles while conducting more research into new technologies, advanced biofuels, and smaller and safer nuclear power. Putting as many things as possible "on the grid" means they can be powered by clean energy. Distributed clean energy sources, better efficiency, and an advanced grid deployed at scale can meet the increased demands of the future. This will be a significant effort, but we have the technology to do it.

Millions of Americans want to personally participate in the clean energy transition, and we need federal policy to help them do so. Limiting emissions will not hinge on any one person's decision to have a cheeseburger or fly for a vacation, but Congress can make clean energy choices accessible to everyone. Investing in clean technologies pays for itself in the long run, but many families cannot cover the upfront cost. Congress can fix this problem, as it has before. In the 1930s, the U.S. government massively increased home ownership by creating institutions that made affordable mortgages possible.[20] Federal action can and should do the same for solar panels, energy retrofits, electric vehicles, and clean technology—and this time around, do so in a way that ensures *all* Americans benefit.

Developing these solutions will drive the next technological revolution for American businesses. With a global marketplace looking for climate solutions, the demand is too great for the United States to ignore.

The other currently available "technology" is our farms, forests, wetlands, and open spaces. Protecting existing natural space and rapidly scaling new natural solutions will help mitigate emissions and turn the warming trajectory back to 1.5 degrees Celsius. Current approaches to carbon sequestration, if applied at scale, can mitigate an additional 9 percent of the United States' current net emissions annually.[21] With the right incentives, farmers, ranchers, and private landowners can significantly contribute to solving the climate crisis and make money in the process.

But we need to be clear-eyed about this—there are solutions we need that we haven't created yet. New R&D will be required to reduce emissions from industrial processes, aviation, and other sectors that are difficult to decarbonize. Developing these solutions will drive the next technological revolution for American businesses. With a global marketplace looking for climate solutions, the demand is too great for the United States to ignore.

BUT CAN WE AFFORD ALL OF THIS? OF COURSE WE CAN. These investments will pay for themselves in new jobs, innovation, and most importantly, avoided costs. We should not be asking whether we can afford to act on climate. We should be asking whether we can afford not to. A failure to reduce emissions will create a real and permanent drag on the economy. Previous economic recessions have been temporary; but without action, severe climate impacts and their damage to our economy will become the new normal. At a certain point, we will not rebound or recover.

Climate change will stunt economic growth because year after year, people and businesses will lose income and their property and other assets will lose value. They will have less money to put back into the economy for more productive uses because the costs of rebuilding and recouping losses will continue to grow. Those costs will crowd out investments in building new things. More frequent and extreme weather events will disrupt operations and supply chains and permanently shutter many businesses. Already, about 40 percent of small businesses never reopen after a disaster.[22] Extreme heat will stress agricultural yields and make outdoor work more difficult and dangerous.[23] Over three million coastal homes in the United States will face inundation from sea-level rise in coming decades.[24] This is in addition to the 4.5 million U.S. homes already at high risk from wildfires[25] and inland homes at risk from river and storm-surge flooding. These households may also lose an essential safety net when insurance companies deem vulnerable areas too risky to insure.

The financial damage of climate change could hit sooner than some of the worst physical impacts. Financial markets pull future risk forward in time, meaning that once investors think an asset will lose value in the future, the price of that asset decreases today.[26] However, markets do not always do this smoothly. Financial firms have historically missed systemic risks, allowing bubbles to build until they burst. When they do, they can spark a financial crisis. For example, at some point before coastal homes become uninhabitable, the value of those homes will plummet. The losses will not just impact homeowners; banks, insurance companies, investors, and millions of retirement accounts will suffer losses too. Similarly, if financial markets continue to ignore that our nation's transition to a clean economy is inevitable, assets tied to fossil fuel reserves and other polluting sectors could be dumped suddenly and disruptively in a "fire sale," rather than through a gradual and intentional shift out of those assets.[27]

THE PRICE TAG ON INACTION IS STAGGERING. According to a peer-reviewed study, under a high-emissions scenario, climate-driven temperature changes alone could cost the United States 9 percent of GDP by 2060 compared to a no-warming scenario.[28] For comparison, during the worst of the Great Recession, real economic output was down 8 percent relative to pre-recession projections.[29] But for climate change this impact could be permanent—essentially, the equivalent of a Great Recession-level disruption *every year*. The drag on the economy will start soon and escalate. Climate impacts could cost us 1 percent of GDP annually starting as soon as 2030. Well before 2040, the cost could exceed 2 percent of GDP each year.[30] This level of loss would be an economic catastrophe. And some impacts—like the change in our quality of life and increased mortality—are more difficult to quantify, but no less troubling.

So what is the alternative? Studies suggest that we can decarbonize 80 percent of the U.S. economy with an investment of 1 percent of GDP *or less* per year. Achieving 100 percent net-zero emissions by 2050 might require 2 percent of GDP per year, due to the harder-to-decarbonize sectors of our economy.[31] It is also important to note that historically, economists have overestimated the cost of technological transformation,[32] and underestimate the economic risk of climate impacts.[33] For example, the costs of inaction quoted above do not account for increasing hurricanes or other catastrophic events, and certainly do not consider the potential for a climate-driven financial crisis. A sensible annual investment in decarbonization now will help us avoid decades of economic decline.

In short, there is no viable scenario in which our country avoids significant spending. We can wait and spend trillions of dollars in a disorderly, unproductive manner to continuously respond to our changing climate. Or, we strategically invest in climate solutions now, largely avoiding the economic drag of inaction and creating conditions for economic growth by investing in the jobs and technologies of the future. When the COVID-19 crisis passes, many politicians will once again say we cannot fund an aggressive transition, and they will demand that Congress take a more incremental approach. But we do not have the choice here. The benefits gained and costs avoided make the case for going big and doing it now.

America made similar investments in the past when it needed to. In the last year of World War II, defense spending comprised about 40 percent of gross domestic product (GDP).[34] This investment pulled the country out of the Great Depression and set up decades of global economic primacy. In the 1930s, we rapidly built a

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national electric grid, going from 10 percent of rural households with access to electricity to nearly 100 percent in 30 years. Bringing electricity to these communities was the catalyst for expansive local development.[35] The same is true for our nation's interstate highways, which provided a 600 percent return on investment over 40 years.[36] We must now make a similar commitment to building a clean economy.

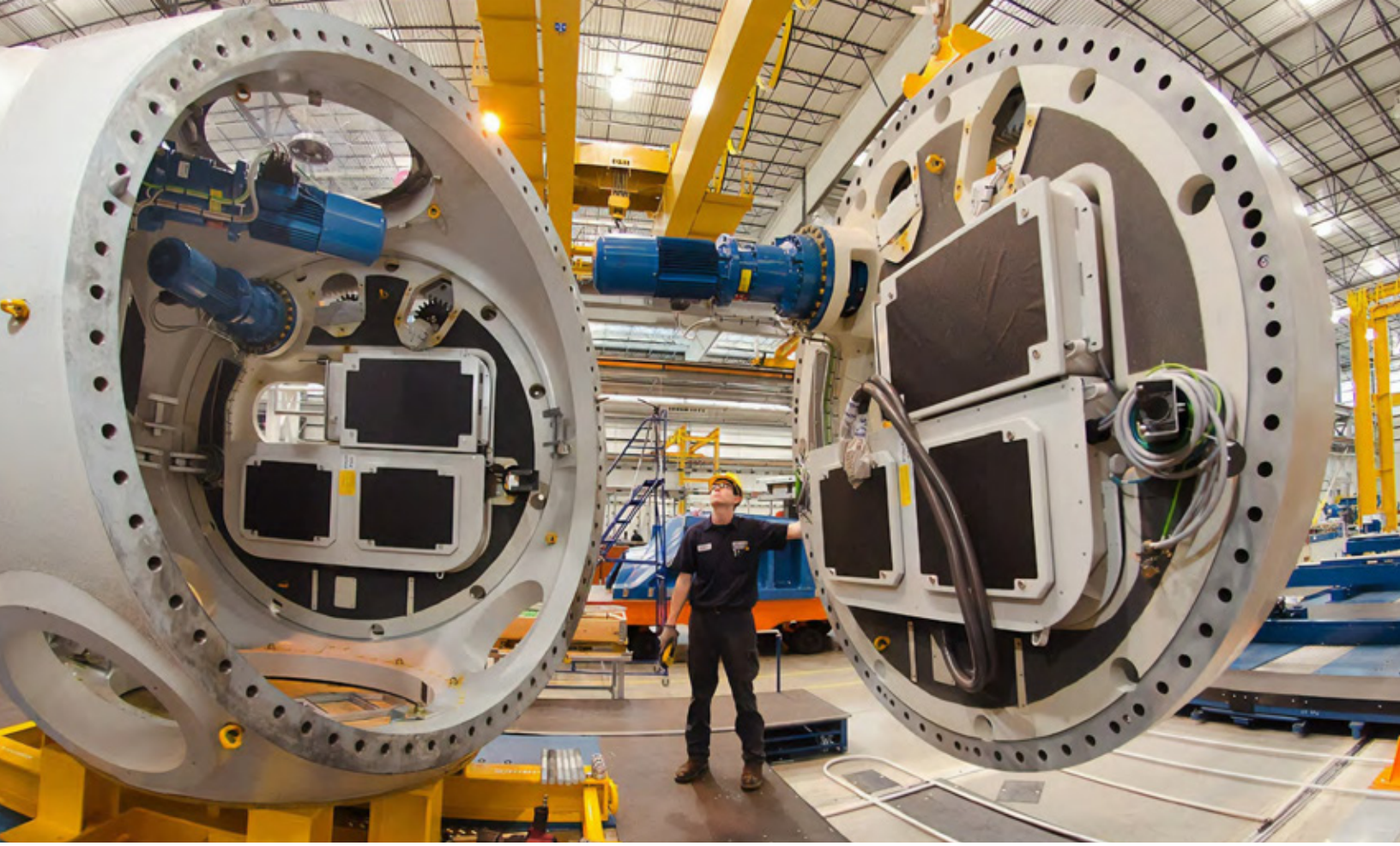
THE MOVEMENT FOR CLIMATE ACTION WILL ONLY SUCCEED IF IT FOCUSES ON PEOPLE, both those who will benefit and those who need extra help. We cannot make the mistakes of previous climate efforts. While the economic benefits of climate action will be significant nationally, those benefits will not accrue equally to every state, every neighborhood, and every individual. We must proactively make targeted investments and create policies that mitigate uneven economic impacts of the climate transition for specific regional economies, individuals, and lines of work—and this effort must be central to any federal climate action.

Overall growth in jobs is important, but so is the quality of careers available.

Climate action is not a two-dimensional problem to be solved by power players in Washington, D.C., and New York City. We must recognize that politicians and financial titans cannot solve this crisis without engaging and earning the support of the people who are affected most. Low-income families and communities of color have traditionally been left out of these conversations, even though they are the most vulnerable to climate change impacts. Our country's history of systemic racism has resulted in these communities experiencing higher levels of pollution and associated health impacts, as well as greater economic and housing insecurity. Climate change will exacerbate these stresses unless there is an explicit focus on mitigating the causes and impacts and addressing the legacy of environmental harms. We need to increase investment in these communities to improve residents' health, grow clean energy generation, reduce energy cost burdens, build resilience to disasters, and diversify and grow job opportunities.

Overall growth in jobs is important, but so is the quality of careers available. Union jobs generally pay about 20 percent more than non-union jobs, and these higher wages are a proven pathway to reducing income inequality.[37] Yet in the last 40 years, union participation has dropped from 20 percent of the workforce to just over 10 percent.[38] Traditional energy sector jobs have historically been high-paying, unionized jobs. But to date, the renewable sector has not replicated the same benefits for its workers. If we are serious when we say climate action provides the best economic opportunity for working people, we have to mean it. There is ample opportunity to create quality careers in clean manufacturing, energy generation, and net-zero construction. The right policies can ensure organized labor grows within the clean economy, and that its members thrive as a result.

The loss of manufacturing and industry nationwide has led to significant job loss and profound impacts on local economies. This is clear in coal country, where some counties and states are largely dependent on the jobs, economic activity, and taxes generated from mining. The market for coal-related jobs has collapsed in recent years, hurting workers, their families, and their towns. We must work with the people who are impacted by this shift to build an economic future and invest in the infrastructure needed to achieve it. But many people have heard this before—and they are rightly skeptical of promises for job training and incentives for education or high-tech opportunities that often do not materialize. These workers and the places where they live are going to need substantial investments, and we need to fully commit to paying.



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CENTRAL TO ALL OF THIS IS CONGRESS. Individual choices will only go so far, and private sector action alone risks continuing the trend of externalizing costs and leaving people out. Only Congress has the power to create nationwide goals, investments, and standards so the whole economy, the weight of the federal government, and the power of American consumers are all moving in the same direction. Through new federal climate legislation, Congress can provide the policy tools necessary to align economic and policy forces and drive deep decarbonization—and craft those tools to stand up to scrutiny by a federal judiciary increasingly hostile to regulatory authority. Congress is also the only body that represents all of us. It can and must create climate solutions that work for everyone. To get the votes in Congress, we need to create a transparent process where diverse voices are heard—not just wealthy individuals and special interest groups. We also need to fully recognize the forces that are working to prevent meaningful climate action and break through the web of misinformation that has been erected to block progress.

THE PURPOSE OF THIS COMMITTEE AND THIS REPORT IS TO SHOW THAT WE CAN SOLVE THE CLIMATE CRISIS—SOLVE IT IN A WAY THAT WORKS FOR PEOPLE AND CAN ACTUALLY HAPPEN. To do that, we engaged a wide range of constituencies. We conducted 10 hearings, spoke with dozens of experts, and received public comments from thousands of people and organizations about the way forward. We reflected on the moral shortcomings of previous congressional efforts on climate action and listened to voices that have too often been ignored in the past. The consensus we reached is a significant breakthrough for climate action in the Senate.

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Legislation must now be developed to meet the overarching goals of the committee:

- ✔ Reduce U.S. emissions rapidly to help achieve 100 percent global net-zero emissions no later than 2050.
- ✔ Stimulate economic growth by increasing federal spending on climate action to at least 2 percent of GDP annually—and ensure that at least 40 percent of the benefits from these investments help communities of color and low-income, deindustrialized, and disadvantaged communities.
- ✔ Create at least 10 million new jobs.

The climate movement is no longer a movement for just environmentalists. It belongs to everyone who wants a strong economy, more and better jobs, a safe and healthy neighborhood, energy security, and an overall better quality of life. We already have so many of the tools and technologies that we need, and there is only upside to investing in what we do not yet have. We also have economics on our side: on one side of the ledger, there are unfathomable costs of damage from inaction, and on the other side are economic opportunities and long-term growth. The coalition for climate action can include all Americans because everyone stands to gain from this new future. Now is the time to put our coalition to work and pass bold climate solutions.

THE ELECTRIC SECTOR

Rapid and drastic emission reductions in the electric sector are technologically possible and can save people money, but we need new federal policy and investments to accelerate the transition.

Americans, rightfully, make a few crucial demands of our electrical system. We want our electricity to be reliable and affordable. Because of the climate crisis, we need it to be low in carbon emissions. And to protect public health, it must also minimize other pollutants, such as particulate matter and mercury. After much innovation, driven largely by public mandates, tax incentives, and investments, it is increasingly clear that all four needs can be met simultaneously. In fact, declining greenhouse gas emissions from electricity generation can drive emission reductions economy-wide through "beneficial electrification." As we move towards the necessary goal of net-zero greenhouse gas emissions by no later than mid-century, the electric sector will be called upon to do much of the heavy lifting.

Currently, electricity generation accounts for 27 percent of all U.S. greenhouse gas emissions.[39] Yet, electric sector emissions have declined rapidly in recent years.[40] From 2005 to 2018, electric sector greenhouse gas emissions fell 27 percent,[41] even while U.S. electricity use increased slightly.[42] Recent emission declines can be mostly attributed to increased energy efficiency and a rapid decline in the use of coal. But we are starting to see a more fundamental shift driven by the growth of clean generation.

By the end of 2019, clean energy supplied over 38 percent of the electricity used in our country, split almost evenly between nuclear power and renewables (including hydropower).[43] Last year alone, the U.S. electric sector added 23,000 MW in new capacity—enough to power millions of homes—with wind and solar installations outpacing new fossil fuel generation nearly two-to-one.[44] And wind and solar account for over 70 percent of the new capacity scheduled to come online in 2020.[45] Still, the U.S. generating fleet turns over slowly, and we are not moving fast enough to avoid the worst impacts of climate change. We need new federal policy to accelerate the pace of this transition.

A very low-emission, or even completely decarbonized, electric sector is not only possible—it is the economically favorable choice.[46] The cost of constructing new renewable generation is nearly even with the costs of running existing coal and nuclear plants.[47] When utilities and independent developers are looking to build new generation, renewables are frequently the lowest-cost option.[48] A recent study found that wind and solar could replace 74 percent of the coal plants in this country and immediately save money for utility customers.[49] Looking forward, installing only no- or very low-emission generators will result in the lowest possible mid-century electricity prices.[50,51] This would also offer health benefits to nearby communities, especially if cleaner electricity is paired with electrification of cars and other technologies that currently rely on fossil fuels.

The federal government must use every proven tool at its disposal—at a greater scale than ever before—to speed the transition to clean electricity and beneficial electrification. These tools include:

- ✔ Direct spending and financing to build new clean generation at a greatly increased pace.
- ✔ Investments in transmission to tie the grid together across the nation via better long-distance connections.
- ✔ A federal clean energy standard, emission standards, a carbon price, and/or other market mechanisms to ensure the rapid adoption and scale-up of proven technologies today.
- ✔ Predictable, technology-neutral tax incentives focused on emission reductions, to enable long-term investment planning.
- ✔ RD&D spending aimed at bending the cost curve for technologies that provide on-demand, net-zero carbon emission electricity.

Barriers still exist to achieving a completely net-zero grid, and we need to invest in finding solutions. For example, rapid advances in short-term battery storage and demand management are facilitating the integration of variable renewables—but the seasonality of wind and solar remains an issue. We must innovate to develop affordable, longer-term storage options that can balance the supply and demand for electricity on the scale of months. We also need to develop ways to reduce the price of on-demand, low-carbon generators, such as geothermal, advanced nuclear, biomass, or fossil generation paired with carbon capture and storage. Since we can't know yet which of these technologies will provide the most affordable path to decarbonizing the last fraction of electric sector emissions, we should develop all potential options now.[52,53]

We will also need a variety of policies to reach net-zero greenhouse gas emissions in a fair and just manner. Current electric emissions and co-pollutants damage public health;[54] particulate emissions alone lead to an estimated 21,000 deaths per year.[55] Low-income communities and communities of color often experience higher levels of these pollutants and resulting health effects. Federal policy must ensure improvements in public health for low-income and environmental justice communities and co-optimize both health and climate benefits.[56]

Federal policies must also mitigate negative impacts of the changing job market. Market forces are already making natural gas and renewable generation more competitive than coal and nuclear plants. The reduction in coal jobs in particular, both in mining and generation, has been devastating for small towns in several states. Nuclear and coal jobs are highly unionized and have long provided good pay that families and communities can build around. Conversely, the number of renewable jobs is growing, but they are more dispersed geographically and unionization rates are much lower than in fossil fuels and nuclear.[57] We need to make targeted investments to ensure displaced energy workers can find new opportunities within their existing communities. We also need new renewable jobs to provide good pay and benefits and strong labor protections.

Given the favorable economics, a nudge from the federal government will help unleash the private capital needed to make our electric generation and delivery system carbon free. This transition will save customers considerable money, improve public health, and if structured correctly, spur reinvestment in communities and workers who deserve fair treatment. A clean electricity sector is a win for taxpayers, workers, families, and the environment.

"[T]he transition to a low-carbon economy will also create new jobs in this country for example in modernizing the grid, in building wind turbines, in solar installations, and in manufacturing electric cars and batteries, and it will increase the valuations of many assets. Ensuring that the intellectual property undergirding these new technologies is developed in the United States as opposed to in other countries is critical to helping the U.S. maintain its technological, scientific, and economic dominance."[123]

— Bob Litterman

Founding partner and Risk Committee chairman, Kepos Capital; chair of the Climate-related Market Risk Subcommittee, Commodity Futures Trading Commission

Cleaner electricity provides many benefits

Reducing emissions and saving money

The electric sector offers the least expensive path to reduced emissions. The technologies needed to achieve deep decarbonization in this sector are both commercially available and economically viable. The most powerful tool for reducing emissions in the short term is increased energy efficiency.[58] Efficiency upgrades allow people to continue to receive the same benefits and enjoy the same level of comfort, while using less power. Much of the potential energy efficiency improvements for production, transmission, and end use of electricity remain untapped.[59]

Across the United States, wind, solar, or natural gas generation already represent the lowest-cost way to generate electricity.[60] And because the fuel is free for solar and wind, they are increasingly hard to beat for lifetime operating costs. A February 2020 report from the U.S. Energy Information Administration shows that on average, solar is the cheapest way to add new generation, followed by wind in second place, and natural gas in third. The costs of solar are expected to continue to decline dramatically through 2050, while natural gas costs are projected to increase over the same period.[61]

A 2020 study found that a 90 percent clean grid can lead to lower electricity prices while creating more than 500,000 net new jobs by 2035, compared to business as usual.[62] Additionally, a 2019 analysis of a federal policy designed to reduce electric sector greenhouse gas emissions by 60 percent by 2035 found that it would prevent 30,000 premature deaths and provide net benefits of nearly $600 billion, while increasing average retail electric rates by only 4 percent.[63]

Because most areas of the country still have relatively low levels of renewables in their electric mix, we can deploy large additional numbers of low-cost wind and solar generators without variability becoming a problem. States and Tribes are already demonstrating that large amounts of renewables can work on the grid without issue.

Iowa and Kansas both received more than 40 percent of their electricity from wind power in 2019.[64] In New Mexico, wind and solar account for 32 percent of electricity generated in the state for 2020 thus far.[65] A solar project built on Jicarilla Apache Nation land will produce enough solar energy to power 16,000 homes per year and move the State of New Mexico closer to its goal of 100 percent carbon-free electricity by 2045.[66] And Hawaii is on track to hit 30 percent renewable generation by the end of 2020;[67] the state already experiences some days when renewable generation approaches 60 percent.[68]

Scaling benefits through electrification

Clean electricity plus beneficial electrification—meaning emission reductions that come when we use clean electricity to replace other fuels—can help decarbonize the rest of the economy while saving money. One recent study of emission reduction scenarios for Colorado showed that complete decarbonization of electricity, 80 percent electrification of automobiles, and 60 percent electrification of space and water heating by 2040 would result in consumer savings of $16 billion on transportation costs ($600 per vehicle per year), $10 billion on heating costs ($500 per customer per year), and $100 in annual electric bill savings per customer. This is even after factoring in the required investments in new technology.[69] A similar analysis for Minnesota, assuming 80 percent economy-wide decarbonization by 2050, found that households would save between $600 and $1,200 per year on energy costs. In this scenario, jobs in Minnesota's energy sector would more than triple, with 14,000 new jobs in wind and 36,000 new jobs in solar, while the cost of electricity would decline 3 cents per kilowatt hour.[70]

Improving public health

A clean electricity transition will improve public health, providing additional indirect economic benefits. As greenhouse gas emissions fall, there is an accompanying decline in emission of co-pollutants, including particulate matter and other air pollutants responsible for respiratory disease. We can save up to 100,000 lives via electric sector decarbonization.[71] Additionally, we can avoid hundreds of billions of dollars in health and other economic losses between now and mid-century.[72,73] These benefits will particularly help low-income communities and communities of color, which are disproportionally impacted by air pollution from the electric sector.[74]

A clean electric sector can bring even more health benefits when electric power is expanded to other sectors of the economy to displace direct burning of fossil fuels.[75] Most conspicuous are the health benefits from electrification of the transportation sector. In Houston alone, estimates suggests that a complete conversion to electric vehicles by 2040 would annually save more than 220 lives, $2 billion, 24,650 asthma attacks, and over 18,000 days of missed school.[76] The air quality improvements brought on by reduced economic activity in response to COVID-19 serve as an example of what could be achieved in times of normal economic activity through greater use of electric vehicles coupled with a cleaner grid.[77]

Creating jobs as part of COVID-19 recovery

The rapid expansion of clean electricity in the last 15 years led to new American jobs. The clean energy aspects of the American Recovery and Reinvestment Act of 2009, and subsequent clean energy tax credits, illustrated how federal investment can pay dividends in terms of job creation that persists long after the immediate economic crisis has passed. Just in the last five years, employment in the clean energy sector grew substantially faster than employment in the overall economy, resulting in more than 800,000 new jobs (Table 1). Clean electricity, and clean energy jobs more broadly, have more potential to rapidly put Americans back to work than almost any other economic lever available when our current pandemic-induced crisis recedes.[78,79]

Table 1: Rapid growth of clean energy jobs

CLEAN ENERGY JOBS	2015[124]	2019[125]	GROWTH
Renewable Generation	413,924	522,811	26%
Smart Grid and Energy Storage	40,020	147,647	269%
Energy Efficiency	1,880,148	2,378,893	27%
Clean Vehicles	169,939	266,368	57%
Total Clean Energy	**2,504,031**	**3,315,719**	**32%**

Table 2: Clean electric generation employs a large number of workers

EMPLOYMENT IN ELECTRIC GENERATION[126]			
Low- or no-emission sources		**Fossil Fuels**	
Solar	248,034	Natural Gas	121,812
Wind	114,774	Coal	79,711
Nuclear	60,916	Oil	12,772
Hydropower	67,772		
Bioenergy CHP	43,520		
Geothermal	8,794		
Total Employment	**543,810** 72%	**Total Employment**	**214,295** 28%

Renewable and low-carbon energy sources are responsible for three in every four jobs in the electric generation sector,[80] with solar energy alone accounting for 35 percent of all such jobs. Solar job growth was nearly 170 percent between 2010 and the beginning of 2020[81] and wind energy jobs grew more than 50 percent in the last five years. Low- and no-emission sources of electricity now account for 72 percent of all U.S. jobs in electrical generation (Table 2).

Even when fossil fuel mining and extraction jobs are added to generation jobs, low- and no-emission electric sources provide 22 percent more of the total electric sector jobs compared to fossil fuels, while only accounting for 37 percent of the electricity on the U.S. grid. That leaves tremendous room for employment growth.

A 2017 study confirmed that the shift from fossil fuels to renewable energy creates a large number of net jobs: $1 million spent on fossil fuels results in 2.65 jobs, while the same amount of spending on renewables results in 7.49 jobs, and $1 million spent on energy efficiency creates 7.72 jobs. Thus, the clean energy transition can create five additional jobs for the same amount of spending compared to fossil fuel generation.[82] A 2020 study also found strong expected net job gains, though it also noted that the transition shifts jobs away from plant operation and towards manufacturing and construction.[83] If there are standards to ensure these are good jobs with strong labor protections, then renewable energy jobs can lead to economic stability for working families.

Given that most of the electric sector projects currently permitted for construction are wind and solar, the clean electric sector provides the bulk of “shovel ready” electric generation projects. Renewable and energy efficiency jobs can be scaled up to ease a labor market depressed by the COVID-19 crisis. Stimulus could also focus on electric transmission and storage: $30-90 billion in transmission investments are needed by 2030[84] and federal stimulus could help get a lot of that work done. Additionally, new rebates or incentives could encourage consumers to buy American-made, high-efficiency electrical appliances and electric heat pumps. That would help restart a portion of the American manufacturing industry while encouraging beneficial electrification.

The risks of inaction: falling behind our competition

The United States is falling behind its main economic competitors in the transition to a clean electric sector. As illustrated in Table 3, China and the European Union are growing clean electricity far faster. From 2009-2018, U.S. wind capacity additions were only 36 percent of the additions achieved in China and 58 percent of what was accomplished in the European Union. The United States lagged behind even more in the solar sector.

Table 3: United States lags behind China and European Union in growth of solar and wind capacity[85]

	2009	2018	GROWTH
Wind Energy Capacity (MW)			
China	17,599	184,665	167,066
European Union	75,312	179,345	104,033
United States	34,296	94,295	59,999
Solar Energy Capacity (MW)			
China	415	175,030	174,615
European Union	17,100	117,005	99,905
United States	2,086	51,450	43,364

Over the last five years, China has invested $540 billion in its wind and solar electric sub-sectors, far ahead of the $232 billion invested in the United States.[86] We also dramatically trail China in the adoption of electric vehicles. China is home to more than half of the electric cars on the road in the world today,[87] though Norway and the Netherlands lead the world by far in per capita numbers of electric vehicles. China has twice as many charging stations per capita as the United States, and the Netherlands has over 20 times the number of charging stations per capita.[88] China has out-deployed the United States in electric buses 420,000 to 300.[89]

The United States leads the world in basic energy research and development and is also well-ranked in applied energy research. Unfortunately, we fall behind our economic competitors every subsequent step of the way from the lab to the actual economy. We have fewer clean energy patents than one might expect given our commitment to basic research, likely due to the relative lack of funding for demonstration projects. Most crucially, the United States is far behind in terms of policies that drive adoption at scale,[90] such as a national price on carbon or national clean or renewable electricity standards. These policies would increase deployment by sending a direct signal to the market that emission reductions are valuable.

Why does it matter if the United States is not keeping pace? The clean energy transition is happening in countries around the world, creating huge demand for clean technologies. A large domestic market is important for developing industries that manufacture clean energy technology for use here, as well as for export. The U.S. economy and American workers can benefit more from the transition if the world is installing U.S.-made wind turbines, or U.S.-made carbon capture equipment, or U.S.-made smart meters, or driving U.S.-made electric vehicles—not the other way around.

Actions to decarbonize the electric sector should protect workers and communities

Addressing the needs of workers and communities impacted by energy transitions

Overall electric demand in the United States has barely grown in the last decade, while inexpensive natural gas generation and renewable electricity sources have continued to grow. This has resulted in an oversupply of generation capacity and driven down the wholesale cost of electricity—impacting high-cost generators, like coal and nuclear plants, the most. These changing market dynamics have brought devastating economic impacts to communities across coal country. Yet at the same time, these changes have provided an economic boom to gas producing regions in Pennsylvania, Texas, and elsewhere, and to windy and sunny parts of rural America nationwide. As we decarbonize the grid, the mix of electric generators will continue to change—and with it the location and number of jobs. Unfortunately, renewable resources are often not located near former or retiring power plants.

The cost to affected workers and communities from the switch from coal to natural gas has been severe. The problem is particularly acute in small towns, where coal plants and mines have been foundational to local economies. We need smart policy and thorough engagement to ensure that no communities are left behind. This means supporting workers both financially and through training opportunities, in addition to targeted investments to rebuild these economies with an eye towards low-carbon industries. The federal government must provide adequate resources to help impacted regions build new economic engines. Additionally, the renewable portion of the electric sector has thus far done a poor job replicating the pattern of high-paying, often unionized, jobs found in other parts of the industry. Federal actions to address decarbonization should promote workers' right to organize, prevailing wage standards, and other pro-worker polices.

Ensuring that low-income communities and communities of color benefit

Low-income communities often face a higher burden of co-pollutants generated by burning fossil fuels; Black Americans are particularly likely to suffer co-pollutant-related mortality.[91] The current "market price" paid by electricity users does not generally account for the social and health costs of environmental pollution. Internalizing these costs would make the economic case for rapid decarbonization and eliminating pollution clear. However, market-based policies alone cannot ensure that all communities will reap the environmental benefits that come from clean electricity. Federal policy must also ensure that national-level emission reductions directly relate to decreased pollution in individual communities.

Low-income communities are also not yet experiencing the benefits of cheaper clean energy. A March 2020 Oak Ridge National Laboratory study paints a stark picture: "Even after decades of weatherization and bill-payment programs, low-income households, on average, continue to spend a higher share of their income on electricity and natural gas bills than any other income group… particularly in the South, in rural America, among minority households, and those with children and elderly residents." This same study also showed that low-income households generally do not have access to government and utility programs that promote rooftop solar power, electric vehicles, and home energy storage.[92] A June 2020 study confirmed that Black households have higher residential energy expenditures than white households in the United States, a difference that appears to be partially driven by differences in housing stock and energy efficiency of household appliances.[93]

Black and Hispanic neighborhoods trail far behind white neighborhoods in the number of homes with rooftop PV solar.[94] Electric vehicles and electric delivery trucks are particularly valuable for improving local air quality, but widespread adoption will not happen unless charging infrastructure is built out in all communities, not just affluent ones. Renewable generation and efficient electric vehicles and appliances offer long-term savings, but we will need targeted federal action to make sure low-income Americans can acquire these advanced technologies.

Environmental justice also demands that low-income and vulnerable communities share in the job growth from a clean electric transition. While numbers are improving, the solar industry lags the overall workforce in terms of employing female and Black workers.[95] And a recent Brookings analysis of the clean energy economy workforce found it is older, more male, and less diverse compared to other occupations nationally.[96] The electric sector transition will lead to large and sustained net job gains in efficiency, construction, and manufacturing. As we build the clean energy workforce, state and federal governments must ensure adequate training and hiring opportunities for members of low-income communities and communities of color. Registered apprenticeship programs provide a particularly valuable avenue for building a workforce tailored to the new skill sets needed in the electric sector.

Driving a faster transition with federal policy tools

A national-scale approach to decarbonization has the most potential to reduce emissions with the least cost. And there are many things the federal government can and must do to drive the transition to a net-zero economy by no later than 2050. But as the federal government steps into this space, we must recognize that states, regions, and certain utilities are already making progress towards decarbonization. Federal action must reinforce, not impede, what states are doing on clean energy, especially those pursuing more aggressive decarbonization.

FEDERAL DIRECT INVESTMENTS AND FINANCING. The clean transition in the electric sector will not proceed rapidly enough without the aid of substantial government investment. These investments are critical to stopping the climate crisis and avoiding the significant costs associated with delayed action.

Direct federal investments are a powerful tool to continue to bend the cost curve of clean technologies and ensure their rapid adoption. A decade ago, the federal government provided more than $90 billion for clean energy as part of the American Recovery and Reinvestment Act. This investment helped pull the United States out of the Great Recession and put more than 240,000 Americans back to work during the height of the labor market crisis. That large-scale deployment was also crucial for driving down the costs of clean technologies, benefits that persist today.[97,98,99] Congress should again direct substantial funds to grow clean energy while putting Americans back to work as we emerge from the current economic crisis. Care must be taken to ensure that these investments reach low-income and underserved communities. The upfront costs of weatherization, energy efficiency upgrades, and new clean technologies should not be a barrier, and appropriate grants can ensure that everyone shares in the economic and environmental benefits these technologies provide in the long term.

Public investments can, and should, leverage private capital by expanding low-cost, easily accessible financing options. Green banks and climate banks have proven to be effective tools for leveraging clean energy investment,[100] and Congress should act to further expand such tools.

A rapid transition to clean energy will require retiring some generators and infrastructure, such as fossil fuel pipelines, earlier than expected and often before capital financing is repaid.[101] Failure to address these stranded assets can leave ratepayers paying off pipelines and power plants that are no longer creating revenue—creating strong disincentives against growing cleaner sources of energy. Securitization and other tools can help utilities retire low-margin, polluting assets early, cut customer costs, and provide impacted communities with tools to ease the burden of transition. Some states, including New Mexico and Colorado, are already supporting securitization for facilities retiring early, but federal action and investment can help scale this solution and address infrastructure that crosses state borders.[102]

CLEAN ENERGY/ELECTRICITY STANDARD (CES). In recent years, states have increasingly turned to renewable portfolio standards (RPS) as a way to increase renewable generation. These policies currently exist in 29 states, generating positive economic and societal outcomes. In 2013 RPS policies supported nearly 200,000 jobs and added $20 billion to GDP, while reducing wholesale electricity costs and providing $7.4 billion in health and environmental benefits.[103]

States and utilities representing nearly 40 percent of U.S. electric sales have made deep decarbonization pledges, with target dates for 80-100 percent emission reductions ranging from the late 2020s to 2050.[104] As we have learned that the "renewables only" electric system is not necessarily the lowest-cost path to net-zero emissions,[105] states have increasingly turned to more technology-neutral, emissions-based clean energy/electricity standards (CES).[106] State action has been essential in achieving emission reductions to date, but a federal standard is needed for nationwide progress. Such a standard could guarantee the electric sector's contribution to meeting the global target of net-zero by no later than 2050, and could include aggressive near-term goals.

Implementing a national CES, restoring and expanding emissions standards, or implementing other strong market signals now will discourage the construction of new assets that will soon become "stranded" or present barriers to complete decarbonization by mid-century. For example, any new fossil fuel assets built today will likely still be in service beyond mid-century. With the right national framework in place, investors will know that such capital investments today will need to be designed to work with zero-carbon fuels or carbon capture technology from the start, or to be easily retrofitted in the future.

MARKET SIGNALS. Harnessing market forces is one of the fastest and most efficient ways to push low-carbon technology from the laboratory to deployment at scale. Tax incentives and direct spending help provide signals of what the market should value. Additionally, some states have shown that carbon pricing is a viable way to value emissions-free energy generation, including the Regional Greenhouse Gas Initiative (RGGI) and the Western Climate Initiative (WCI). The 11 states participating in these multi-state agreements represent a third of gross domestic product and over a quarter of the U.S. population.[107]

Carbon pricing mechanisms are an option for driving the transition to a clean economy. Federal policy aimed at harnessing market forces, however, must be careful to provide guardrails to ensure that national-level gains don't mask stasis or backsliding in individual communities on air quality or environmental justice issues. Additionally, market policies must be designed to protect trade and competitiveness of domestic goods. One noteworthy benefit of market approaches that price carbon is that they can generate significant near-term revenue. Several existing proposals in Congress include uses for these resulting revenues, either refunding the money to American taxpayers or reinvesting the revenues to speed the pace of the clean transition and address social justice issues.

TAX POLICY. Federal tax credits have been essential in scaling the deployment of wind and solar generation.[108,109] But while federal tax and subsidy policy has helped renewable energy growth, it currently helps fossil fuels more. For example, in 2016, the federal government provided $7.8 billion in subsidies and tax incentives to encourage renewable electricity. Yet, those programs are temporary and subject to constant congressional renegotiation; all have subsequently expired, or soon will. At the same time, the federal government provided substantial subsidies for fossil fuels (2016 estimate range is $5-20 billion) through incentives permanently written into the tax code and which continue to pay out year after year.[110,111,112] Additionally, by not internalizing the huge environmental and health costs associated with burning fossil fuels, the U.S. government effectively further subsidizes those sources by hundreds of billions of dollars per year.[113]

Going forward, tax incentives can continue to play a critical role in the transition to a net-zero greenhouse gas emission electric sector. Overall energy tax policy should be focused on the desired outcomes: reducing emissions and providing reliable and affordable electricity. Furthermore, based on past experience, tax policy must be more predictable to help with long-term investment planning.

Innovation in clean energy is necessary and expected, so tax policies put in place today should be flexible enough to include future technologies that are not yet known or viable. Ideally, the tax framework should be technology-neutral and emissions-focused. We also should not forget that tax credits cost the American taxpayer just as direct federal spending does. When the federal government provides companies with taxpayer resources, it is reasonable, when possible, to link those benefits going forward to the use of project labor agreements and other methods for ensuring support for American workers and communities.

Federal action can drive change across a diverse, complicated U.S. energy system

Aligning goals, incentives, and policies

The United States has a complicated electrical system that involves multiple owners and operators, ownership models, and complicated regulatory structures for the generation, transmission, and distribution of electricity. The continental United States is divided into three large electric grids with minimal ability to move actual electrons between them. These large grids are then divided into smaller areas, which are organized with national (primarily the Federal Energy Regulatory Commission, or FERC), regional, and state-level entities providing structure, oversight, and regulation.

Electric utilities themselves operate on one of three ownership models: investor-owned utilities, public utilities, and electric cooperatives. To add to the complexity, some states operate regulated electricity markets where local monopoly utilities own everything from the power plants to the wires that enter a customer's home, with rates being set with oversight from a public utility commission. Other states operate deregulated markets where utilities own neither power plants nor the transmission lines. Depending on their structure and location, utilities have varying needs, incentives, and access to capital. Rural areas pose unique cost challenges arising from the low number of consumers per mile, which caused a long delay in the electrification of rural America compared to urban centers. Federal policy helped bridge this gap through the creation of rural electric cooperatives and large public power authorities, such as the Western Area Power Administration and the Tennessee Valley Authority.

Federal policy must work through all these existing complexities and constraints and guide the actors and investments in the grid toward a new paradigm. Different regions have different potential access to types of low- or zero-carbon power. Some places have good wind, some have good solar, some have neither. Federal policy that is technology-neutral and emissions-focused can provide needed nationwide goals and standards while also allowing different regions to utilize their specific resources.

Within this complicated electrical system, FERC plays a critical role in regulating interstate transmission and the wholesale sale of electricity across state lines. Unfortunately, under the Trump administration, FERC has become increasingly politicized and has actively worked to undermine the clean energy transition and interfere with state and regional-level action. The next President and Congress must ensure that FERC does not stand in the way of states, regions, and utilities looking to decarbonize.

Balancing the incentives of utilities and other market players with the needs of the public will always be difficult. Public utility commissions (particularly in regulated states) are beginning to institute "performance based ratemaking" (PBR) where the rates that utilities are allowed to charge customers are partially based on goals like efficiency and emissions reductions. In 2019, 19 states were moving towards a PBR model,[114] up six from the year before.[115] Federal policymakers and regulators should be equally creative.

Balancing the need for both large-scale and distributed electricity

Large, utility-scale wind and solar farms currently enjoy a large cost advantage over small, distributed generation. Yet, there is an important role for small-scale distributed generation, which can help provide resilience during natural disasters and meet equity and environmental justice goals. Ownership of generation in low-income communities can help spread the benefits of clean energy and create local clean energy jobs in those communities as well. Net metering policies make it economical for individuals to participate in power generation and turn otherwise unused roof space into a source of clean electricity. Solar community gardens and similar projects can also help meet local goals at a lower cost than individual rooftop installations.

An underappreciated feature of regulated energy markets is that utilities tend to sell electricity at cost; their profits come from guaranteed rates of return on infrastructure that they build and own. As a result, utilities are incentivized to expend time and resources discouraging the development of distributed energy—particularly generation sources that the utility does not own. Additionally, no utility would prefer to purchase electricity at retail prices from individuals with solar panels when wholesale alternatives are available. This creates a strong incentive to dismiss the value of distributed resources to the electric sector and to customers. Policymakers must develop solutions to this conundrum that are fair for all involved, but ultimately states should be allowed to pursue net metering and similar policies without federal regulations that artificially increase the costs of renewable ownership by individuals.

THE ELECTRIC SECTOR IS AT RISK FROM CLIMATE CHANGE

While the electric sector is crucial for emission reductions that will help us avoid the worst climate impacts, climate change also poses a direct threat to the U.S. electric system itself.[127,128] Some of the risks are already on the evening news. As climate change leads to higher temperatures and droughts, fire dangers increase. As the heat rises, electrical wires sag dangerously into dry vegetation that becomes kindling for increasingly extreme forest fires. Recent fires in California and Australia provide striking illustrations; and Californians have endured and will continue to experience intentional power outages brought on in an attempt to reduce fire risks.

Air conditioning places heavy stress on the electric system during heat waves, and the efficiency of thermal generators (coal, natural gas, and nuclear power plants) and solar panels decreases as temperatures rise. As the climate changes and temperatures rise, demand for air conditioning is already straining the electric grid. Climate-induced droughts also threaten thermal generators, which rely on extremely large volumes of water for steam generation and cooling. Biofuels require ample water to grow plants, oil and natural gas extraction rely on large volumes of available water, and most obviously, hydropower production falls during times of drought. Changing precipitation and snow pack patterns also threaten existing hydropower infrastructure, which is increasingly in the wrong place as the climate changes.

In many places, climate-driven storms and sea level rise threaten electric infrastructure. Hurricane Maria's impact on Puerto Rico in 2017 tragically demonstrated the effects large hurricanes can have on an electrical system. Because coal, natural gas, and nuclear power plants need so much water, they are often located on coasts, lakes, or near rivers, and are particularly susceptible to flooding and sea-level rise. On the other hand, wind and photovoltaic solar generators do not require water for cooling, and are therefore less frequently installed in areas susceptible to these risks. The resilience of our electric sector will depend on building new infrastructure that is hardened against our changing climate.

New clean energy infrastructure will require national planning and investments

Federal infrastructure investments can help accelerate the clean electric transition in many ways, and a priority should be to increase investment in interstate transmission. Clean energy is often generated in rural areas, far from urban centers where electricity demand is concentrated. A transmission system optimized for highly distributed renewable generation is starkly different from our current transmission system based on centralized fossil fuel generation. New, carefully crafted federal policy can encourage timely construction of new transmission lines without compromising the integrity of environmental review. Federal efforts should strive for coherent and strategic transmission investments. A more unified national grid with better long-distance connections would require substantial initial investment but would also offer tremendous benefits.[116]

Decarbonizing the electricity sector (and industrial sector) will also require new types of interstate pipelines. The United States already has nearly 5,000 miles of pipeline to carry carbon dioxide,[117] but we will need thousands more miles if we commit to a carbon capture and storage network that scales to the likely need. All scenarios examined in the 2018 IPCC report on holding global warming to 1.5 degrees required the use of carbon capture and storage.[118] We may also need new pipelines to carry hydrogen or other chemicals created to store electricity produced by wind and solar generators. Like new transmission, new pipelines are challenging to permit. To achieve emission reduction goals, we will need well-crafted federal policy changes to aid the buildout of this pipeline network without sacrificing environmental review processes.

Energy efficiency saves customers money and can help meet mid-term reduction goals

Twenty-eight states have policies collectively known as “energy efficiency resource standards” that mandate utilities meet increasing targets for energy efficiency. These lead to a variety of improvements in the generation and transmission of electricity and also provide utilities with an incentive to help their customers reduce electricity use. While it may sound counterintuitive for a utility to want to decrease demand, and therefore revenue, decreasing demand at peak times actually saves the utility money by not having to build excess peak generation capacity. Congress could set a federal efficiency standard that would open up the potential for a national trading market in efficiency credits and lead to more reliably low-cost solutions.

Efficiency improvements often require large upfront capital expenditures. Energy savings performance contracting provides a potent tool for overcoming that initial hurdle. Energy service companies (ESCOs) are rapidly growing in the United States; they provide the upfront capital and recoup their costs by taking a percentage of the energy savings delivered to their customers. But when the upfront expenditures are very large or the payback period is too long for private ESCO companies, additional federal investments and policies can drive the adoption of energy savings improvements. For residential efficiency, federal policymakers must take great care to ensure benefits reach all Americans, particularly low-income and minority communities. We will need creative new policy to overcome the unfortunate “incentive disconnect” that is common for rental properties: renters suffer from inefficiencies via high utility bills while property owners—who often don’t pay the energy bills for the rental properties they own— see little return for investing in efficiency upgrades.

We need to make additional investments in research, development, and demonstration (RD&D)

The rapid decline in electric sector emissions in recent years was built on past federal research investments that led to cheaper natural gas and steep cost reductions for wind, solar, and battery storage technologies. Additional research can further bring down the price of clean generation technologies and increase electric sector efficiencies. Scientific breakthroughs are most needed for technologies that can address the unique problem of fluctuations in wind and solar energy on monthly, seasonal, and yearly timescales.

Addressing variability in renewable resources

The variable nature of wind and solar resources is often cited as a barrier to rapid expansion of these forms of energy. In fact, the U.S. electric system can already absorb far more low-cost wind and solar generators than are currently deployed. Variability is no reason to delay building the wind and solar generators that are crucial to meeting short- and long-term climate goals. However, variability on the order of months and seasons is a real medium- and long-term obstacle to overcome, and federal energy RD&D investments should be increased and focus on lowering the costs for the tools necessary to provide on-demand, net-zero carbon emission electricity.

> "A just and equitable low-carbon future must be founded on optionality, flexibility, and innovation to accommodate regional differences in energy resources, infrastructure, jobs, technology needs and costs."[129]
>
> **— Dr. Ernest Moniz**
>
> *Former Secretary of the U.S. Department of Energy, and president and CEO of Energy Futures Initiative Inc.*

In a grid with high levels of wind and solar generators, electricity will be overproduced when it is windy and the sun is shining. To make such excess production useful, it needs to be cost-effectively stored. Battery prices are falling rapidly, and advances in utility-scale energy storage are increasingly making it possible to use battery storage to match renewable energy production to demand.[119] The best example of this is the growing tendency to pair solar with batteries that can release electricity at night. Battery storage can also help solve an economic problem for solar energy: since solar energy peaks during specific hours of the day, each new solar panel directly competes with existing panels. At high levels of solar energy adoption, the cost of electricity can essentially fall to zero during sunny hours, a challenge to the profitability of all generators seeking to sell electricity and a particularly potent disincentive to adding new solar generation.[120]

However, affordable batteries currently only store electricity for a few hours, and the availability of electricity from wind, solar, and hydropower generators vary not only day-to-day, but also season-to-season. This begs for the continued development of affordable new long-term methods to store energy that can be used in a variety of contexts. Currently, most long-term electric storage in the United States is in the form of pumped-storage hydropower,[121] but large-scale new hydropower projects can have many environmental downsides and are dependent on suitable hydrography and topography. Other technologies are not yet available

for cheap, widespread deployment. Storing energy as hydrogen or in other chemical forms is promising[122] and would have the added benefit of providing fuel that can be used to provide carbon-free energy for other sectors of the economy. The federal government needs to increase investment in developing and manufacturing improved batteries and other long-term storage solutions.

The alternative to long-term storage is continued and increased reliance on electrical sources that do not release greenhouse gases and can be dispatched whenever needed. Advanced nuclear generation and geothermal generation could meet that requirement, but both are expensive and have other limitations that must be overcome. The United States still lacks a comprehensive strategy on how to store nuclear waste, and some communities where nuclear power is generated or waste is stored have expressed safety and security concerns. Congress should pursue a consent-based siting process when addressing the disposal of our nation's nuclear waste and provide support to communities that are currently grappling with stranded nuclear waste.

The other option is the use of fossil fuel generators paired with carbon capture and storage technologies to recapture the resulting greenhouse gas emissions, though it is vitally important that other co-pollutants, such as particulate matter and ozone, are controlled as well to protect public health. The same considerations apply to electricity from biomass. When paired with carbon capture and storage, biomass can potentially contribute to "net-negative" carbon emission electrical generation. However, biomass is not available in quantities sufficient to meet a large fraction of electric demand, and biomass energy policy must be extremely carefully designed not to encourage deforestation, destruction of biodiversity, additional air pollution, and erosion of crucial carbon sinks in soil and vegetation. Additional RD&D on advanced nuclear, geothermal, carbon capture and storage, and biomass technologies will decrease their costs and improve their efficacy.

THE INDUSTRIAL SECTOR

> Getting to net-zero emissions in the industrial sector will be challenging, but it is a crucial component of addressing the climate crisis. If done right, this transition will create jobs, revitalize deindustrialized communities, advance environmental justice, strengthen our manufacturing and domestic supply chains, and enable us to export clean technologies to the rest of the world.

Since 1980, deindustrialization has harmed American workers and communities. Manufacturing has shed over 5 million jobs,[130,131] devastating communities across America, especially in the Great Lakes and Southeast regions.[132] The last decade of continuous economic growth nationally did not change these trends for many locations. Deindustrialized communities face increased poverty and a legacy of industrial pollution that hinders new economic opportunities.[133] Federal action to reduce emissions, if designed correctly, can help reinvigorate U.S. manufacturing in these communities, growing local economies and creating good jobs, while at the same time addressing the environmental justice needs in communities that are too often neglected.

The United States' industrial sector is a testament to American ingenuity and hard work, and has been a driving force for the American middle class for generations. Prior to the COVID-19 crisis, American manufacturers employed 8.5 percent of the workforce—about 13 million people[134]—and these workers contribute 11.4 percent of the total U.S. GDP.[135] American manufacturing jobs are good jobs: compensation is 13 percent higher than comparable jobs in the American economy.[136] While manufacturing and other industries are a vital source of income and economic activity, they do take a toll on our planet, emitting 29 percent of total U.S. greenhouse gases when including indirect emissions.[137] To avert the climate crisis—and for the United States to do its part toward achieving the target of global net-zero emissions by no later than 2050—we must rapidly decarbonize this sector.

The solution is to provide a massive investment in advanced and clean manufacturing to solve the dual problems of outsized emissions from the sector and a shrinking job base. We can solve both problems at once with the right set of policies.

But this won't be easy. Compared to other sectors, industry presents a number of difficult challenges for achieving net-zero emissions. Thousands of different products are fabricated at hundreds of thousands of factories using a large number of different processes. Due to this diversity and complexity, varied approaches to emission reduction are required. There is certainly no 'one-size-fits-all' technology available. Additionally, there are currently no zero-carbon substitutes for most products and materials that Americans use every day; new alternatives need to be discovered and developed.

Decarbonization is necessary, yet large-scale investments and research breakthroughs are required before we can make a fully decarbonized industrial sector a reality. For example, energy efficiency measures and electrification can be implemented now for short- and intermediate-term emission reductions. Looking forward, we must scale solutions that have the biggest impact. Importantly, growing the use of low-carbon fuels, such as hydrogen, will enable the replacement of fossil fuels currently used to provide industrial heat. And we need to make carbon capture, utilization, and storage (CCUS[i])[138] cost-effective, safe, and reliable for processes that cannot run on clean electricity or fuels, while also supporting natural and low-tech carbon storage solutions. Finally, continued innovation will bring to market new products that produce low or no emissions during the manufacturing process.

This transition to lower—and eventually net-zero—emissions provides an opportunity to rethink, modernize, and reinvest in how we make things. The federal government can support this by:

- ✔ Incentivizing existing technology and tools, such as industrial efficiency, now.
- ✔ Providing the incentives, direct investments, and access to financing needed to grow new clean jobs, especially in those communities that have previously seen the loss of manufacturing jobs.
- ✔ Using tax credits and other financial and policy levers to reward 'cleaner' products and discourage high emissions.
- ✔ Using government purchasing power to create a market for lower-emission materials, similar to Buy America/n procurement standards.
- ✔ Developing national infrastructure systems that support low-carbon technologies, like hydrogen and CCUS.
- ✔ Implementing federal emission standards for the industrial sector, coupled with policies that protect American manufacturers from unfair competition from goods that are produced in an environmentally damaging manner elsewhere.
- ✔ Enforcing strong policies to protect communities from co-pollutants that damage public health.
- ✔ Developing and driving a broad innovation agenda to support RD&D in novel materials and processes, industrial CCUS, smart manufacturing, low-carbon fuels, and other breakthrough technologies.
- ✔ Investing in demonstration projects for new technologies that would not otherwise be funded by the private sector alone.

i Carbon utilization: the manufacture of valuable products from a gaseous carbon waste feedstock (carbon dioxide or methane) that results in a net reduction of greenhouse gases emitted to the atmosphere.

"Long-term, there will likely be technologies and opportunities that we have yet to conceptualize. [...] Given the challenges..., Congress should direct and fund this research, development, and deployment now to make sure facilities are able to retool over the coming decades to meet our climate goals."[196]

—Thomas M. Conway
International president, United Steelworkers

As we invest in decarbonizing industry, we must support American workers and companies. Our actions should include pro-worker polices that guarantee protections and create family-sustaining wages. Additionally, as we demand that our U.S. manufacturers employ cleaner technologies, the federal government must safeguard American jobs against unfair competition from foreign-made products that still rely on high-emissions production or on cheap labor performed by workers without labor protections.

The world is moving towards a low-carbon economy, and consumer demand for low-carbon products is growing. The United States is at a critical juncture: American manufacturing and American jobs are at risk. But if we act quickly to drive a rapid transition to net-zero, our companies and workers will be able to fulfill this global demand with American-made clean products and clean technologies.

The industrial sector is a large source of greenhouse gas emissions

The industrial sector accounts for 22 percent of total U.S. greenhouse gas emissions, 29 percent if indirect emissions due to electricity use from off-site power plants are included.[139,140] Carbon dioxide emissions from industrial sources can be grouped into three main categories: electricity use (25 percent of emissions), combustion of fossil fuels for heat (40 percent), and other emissions caused by manufacturing and chemical processes (35 percent).[141] Other greenhouse gases are also released through industrial activity, including methane and fluorocarbons.

Due to its complexity, there is no easy solution

"Industry" is made up of many distinct activities (Table 1) that each employ their own unique processes and release greenhouse gas emissions in different ways. Each will likely require its own decarbonization solution.

Iron and steel, chemical and plastics, and cement are responsible for over half of the emissions,[142] so large gains can be achieved by focusing on these three industries. As one example, American steel manufacturers have already reduced emissions by swapping out furnaces that burn coal with electric arc furnaces that use electricity. Due to facility efficiency and use of electric furnaces, the emission intensity of U.S. steel is fourth-lowest in the world and less than half of the emission intensity of Chinese steel.[143]

Yet, these gains are already showing the need for the United States to protect competitiveness as we continue to decarbonize. There is currently an oversupply of global steel and no market signal that values reduced emissions or stronger labor protections. These conditions encourage U.S. businesses to import cheap, but high-emission steel rather than turning to cleaner, domestic supplies produced by unionized workers making decent wages. In a world where emissions have no cost, cleaner American steel will lose out to more emissions-intensive Asian steel.

Table 1: 2014 global greenhouse gas emissions from top industrial sectors[197]

INDUSTRY	EMISSIONS [MT CO_2E]	PERCENTAGE OF TOTAL INDUSTRIAL EMISSIONS
Iron and Steel	3,487	20.7%
Chemicals and Plastics	3,347	19.9%
Cement	2,545	15.1%
Aluminum	1,109	6.6%
Refining	950	5.6%
Machinery	937	5.6%
Pulp and Paper	836	5.0%
Ceramics	754	4.5%
Food and Tobacco	694	4.1%
Other Metals	407	2.4%
Lime	263	1.6%
Construction	188	1.1%
Glass	154	0.9%
Wood and Wood Product	102	0.6%
Other Industries	1,068	6.3%

Inaction risks the United States falling behind international competition

The United States is a world leader in manufacturing and production, but failure to address climate change puts this at risk. Inaction means jobs will grow overseas instead of here, and it will increase the United States' dependence on foreign-made technology and products.[144] The COVID-19 crisis has demonstrated the vulnerability of the U.S. economy to uncertain global supply chains.[145] But if we take action now, we can strengthen our manufacturing sector and domestic supply chains, increase good jobs, export clean technologies to the rest of the world, and invest in deindustrialized communities.[146]

Other countries and regions are beginning to implement policies to reduce industrial emissions and develop the technologies needed to decarbonize. For example, the European Union's Emissions Trading Scheme (EU ETS) establishes baseline emission requirements for select industrial activities, encourages "best available techniques" for emission reductions, and bans the use of hydrofluorocarbons (HFCs)—a very potent greenhouse gas—in select new equipment.[147] Other countries, such as Germany and Japan, have also implemented financial incentives and support schemes that promote R&D, fuel-switching, and material efficiency within the industrial sector.[148] These changes will increase global demand for low-emissions products.

History has demonstrated the consequences for American competitiveness when other countries lead in meeting this demand. Though solar photovoltaic technology was invented in the United States, China is the world's leading manufacturer of PV panels[149]—controlling about 70 percent of global market share. The Chinese government chose to prioritize renewable energy manufacturing through loans, tax incentives, and complementary policies, and American solar companies and workers suffered.[150]

INDUSTRY IS AT RISK FROM THE IMPACTS OF CLIMATE CHANGE

This sector is not immune to the risks and impacts of a changing climate. Many major industrial facilities are located in coastal areas that are vulnerable to sea-level rise, increased flooding, and extreme weather events.[198] For example, Texas refineries, which represent 31 percent of all U.S. refinery capacity, were hit hard by Hurricane Harvey in 2017 and forced to reduce production, leading to supply chain challenges throughout the country and increased gas prices.[199] Many import/export terminals for transportation of goods are located in areas susceptible to sea-level rise, and flooding along major rivers and lakes within the United States will disrupt transportation of key materials needed for manufacturing.[200] High water levels in the Mississippi River and Great Lakes can limit shipping. Additionally, flooding and impacts from other natural disasters, like hurricanes, can cause local pollution in these areas. Finally, higher temperatures and increased extreme weather events will reduce worker productivity.[201] Companies need to invest in making these facilities more resilient, which in turn will improve the resilience of our supply chains.

Policies to decarbonize should protect U.S. workers, companies, and communities

Protecting American factories and workers in trade policies

Many industrial products are energy-intensive and trade-exposed. As we institute domestic decarbonization policies that increase overall production costs, we need to address this reality by adopting accompanying policies to retain competitiveness. If we do not account for the emissions of imported goods, we could see U.S. companies shift their production to countries that are less strict on carbon emissions—a process referred to as "carbon leakage."[151] This will not only lead to an increase in total global emissions, but also the outsourcing of American jobs. Protecting the American worker and American competitiveness in international markets is a vital component of any industrial emission reduction policy.

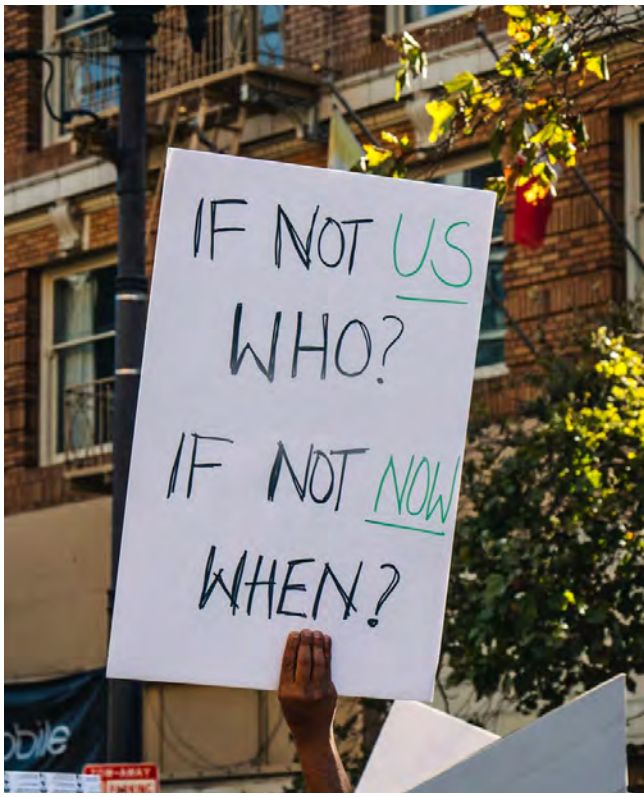
The United States must also strive to keep our goods competitive for export. Other countries are already considering low-emissions trade policies. The EU is pursuing a "carbon border adjustment mechanism" to protect EU companies from cheaper, high-carbon imports,[152] a step that is already worrying some trade partners.[153] U.S. products could increasingly be disadvantaged in the global market if they don't meet international emissions standards. We must get ahead of this movement and develop our own federal standards and carbon tracking mechanisms for emissions reductions. Other countries have shown a greater commitment to investing in and supporting a clean transition, and they will not be reluctant to implement trade policies that favor their own cleaner production. If we move quickly, we can help set the terms of these trade arrangements. If not, other governments will set the international agenda.

Growing economic opportunities in deindustrialized communities

The United States' current investments in economic development have not done enough to help former manufacturing communities recover from the hardships of deindustrialization. But addressing the climate crisis provides an opportunity to right this wrong. Congress should create policies, including investments, incentives, and financing mechanisms, that encourage and support new clean manufacturing jobs. We should make these investments in the United States' most economically distressed communities, particularly those that have lost manufacturing and industrial jobs in the past. However, new factories cannot just be located in low-income communities; their residents must also economically benefit. This means a federal commitment to supporting education, training, and Registered Apprenticeship programs for underserved populations to gain good-paying jobs in cleaner industries.

Supporting workers' rights

Traditionally, American manufacturing jobs pay better than many other middle class careers. However, the "manufacturing wage premium" has declined since the 1980s.[154] At the same time, union representation across all sectors fell from 20 percent to 10 percent.[155] New jobs in the clean industrial sector must provide family-sustaining wages. To ensure this, workers' right to organize, prevailing wage standards, and other pro-worker policies should be prerequisites, whenever possible, for all federal investments to reduce emissions, including government contracts, direct aid, or tax incentives.



Protecting public health in low-income and frontline communities

Industrial facilities remain a major source of co-pollutants and other environmental toxins that disproportionately impact low-income and minority communities.[156] 'Cancer Alley,' for example, is one of the most polluted places in the United States, due to a heavy concentration of petrochemical plants. The alley runs about 85 miles along the Mississippi River, from New Orleans to Baton Rouge. The public health burden associated with co-pollutants in this region is acutely concentrated in predominantly poor and minority communities.[157] There are similar, if less well-known, examples spread throughout the country, each of which starkly illustrates the need to account for the cumulative burden of exposures to residents in vulnerable communities. Racial disparities in exposure to pollution are no accident. Discriminatory real estate practices—such as redlining—mean that communities of color are often near heavy industry and legacy Superfund sites.[158,159] This consistent pattern of environmental injustice causes communities of color to face disproportionate health risks. And while eliminating carbon dioxide pollution is necessary in combatting the climate crisis, it is only part of the solution. Eliminating exposures to the range of environmental pollutants in vulnerable communities and populations must be an independent, intentional, and carefully monitored goal.[160] To do that, the federal government must enforce existing laws, such as the Clean Air Act and the Clean Water Act, and develop new policies to fill any gaps.[161]

Creating market certainty for company investments

Industrial facilities are large, capital-intensive, and full of equipment that is built to last decades, making consideration of stranded and semi-permanent assets an important part of any decarbonization policy. Companies that invest in newly built or upgraded factories assume those capital investments will still be operating in several decades—often past the point at which we will need to achieve net-zero emissions. Industry currently lacks the regulatory or market signals that would motivate the development and use of net-zero emitting technologies. A federal commitment now to decarbonize no later than 2050, along with other market mechanisms designed with this goal in mind, can provide the certainty companies need to plan for the long term when making significant capital investments today.

We have tools to significantly decarbonize the sector, but we need more

Some solutions can be deployed on a large scale right now. Others need more research and development to make them cost competitive, while still other technological breakthroughs are only now starting to be developed.

Achieving easy gains through efficiency

Efficiency improvements can be employed immediately to reduce emissions from the three top-emitting industrial sectors (iron and steel, chemical, and cement), while simultaneously reducing costs and increasing productivity.[162] Energy and process efficiency, as well as recycling and re-use, will improve overall use of materials and energy. For example, replacing pumps, fans, and other equipment with more efficient, properly sized models can reduce emissions and lower electricity costs.[163] Strategic energy management and smart manufacturing practices can reduce industrial emissions by 15 percent, and new technologies, processes, and fuels, including electrification, can reduce industrial emissions by an additional 14 percent.[164] Table 2 illustrates these potential energy savings—and associated emissions savings—using current state-of-the-art technology, and additional energy and emission reductions that can be realized as R&D investments come online.

Table 2: Top three highest emitters with identified energy savings and processes per industry[165]

	IRON & STEEL	CHEMICAL & PETROCHEMICAL	CEMENT
Current Energy Consumption	**999 TBtu/yr** (2015) (equivalent to 13 million U.S. households166)	**3222 TBtu/yr** (2015) (equivalent to 42 million U.S. households)	**245 TBtu/yr** (2017) (equivalent to 3 million U.S. households)
Potential Energy Reductions	**240 TBtu/yr** With current state-of-art technology. **+150 TBtu/yr** potential savings from R&D	**766 TBtu/yr** With current state-of-art technology. **+ 1176 TBtu/yr** Potential savings from R& D	**62 TBtu/yr** With current state-of-art technology. **+7 TBtu/yr** Potential savings from R&D
Processes	Largest savings in hot rolling, cold rolling and other processes.	Largest savings in improving basic organic chemical and plastics materials and resins	Largest savings in crushing/grinding, pyro processing and finishing grinding

Combined heat and power (CHP) and waste heat to power (WHP) are other energy efficiency technologies that could be significantly expanded to reduce emissions and lower costs for the industrial sector. CHP produces both electricity and heat from a single source of energy.[167] The waste heat that would normally be lost during electric power production is captured by CHP technologies and used elsewhere for heating, cooling, or other industrial applications.[168] CHP systems have an expected efficiency of 65-75 percent, an increase of up to 25 percent over traditional systems.[169] WHP involves capturing waste heat from industrial processes and heating and turning it into electricity.[170] There are up to 14.6 gigawatts (GW) of untapped waste heat to power capacity in the manufacturing sector in the United States, enough energy to provide electricity to an estimated 11 million homes every year.[171]

Addressing industrial emissions through clean electricity

Cleaning up the electric grid has a spillover effect in reducing emissions in all other sectors. Twenty-five percent of emissions associated with industrial production can be eliminated with a net-zero emissions grid. Pathways to reduce emissions from the electric sector are well understood, and the technologies needed are commercially available and economically viable.[172] Significant price drops in renewable energy have already led factories and manufacturing facilities to switch to renewable power.[173] Greater emissions reductions are possible through electrifying additional processes. For example, some low-temperature furnaces, typically considered to be anything below 750 degrees Fahrenheit, can replace fossil fuel combustion with electric heat.[174] Electric heating has other advantages, including high controllability of temperature, precise duration of heat application, and low maintenance.[175] However, switching from the use of fuel to electricity for heat is not trivial—it often requires significant modifications to equipment, and industrial heating requires large quantities of non-variable electricity.

Switching fuels for high-temperature heat

Many industrial processes require high-temperature heat, which is not suited for replacement by electrification.[176] For example, making cement requires temperatures of 2,500 degrees Fahrenheit, and melting iron ore to produce steel requires temperatures of 2,200 degrees Fahrenheit.[177] One way to address these emissions is the use of low- and zero-carbon fuels, such as hydrogen, ammonia, and biofuels. Zero-carbon solutions are also being developed, such as advanced concentrating solar power, to generate the high heat needed for such industrial processes.[178] Our innovation agenda needs to advance and scale hydrogen or other low/no-carbon energy sources across numerous sectors and to expand the national infrastructure needed for transport and storage.

THE PROMISE AND POTENTIAL PITFALLS OF HYDROGEN

Hydrogen is a promising fuel because it can be used across the electric, transportation, and industrial sectors. These multiple uses make investments in hydrogen infrastructure broadly beneficial. Additionally, hydrogen can be used as a long-term storage solution for excess wind and solar energy, by producing hydrogen via electrolysis when renewable energy production is high and then burning that hydrogen to produce electricity when variable renewable energy production is low.[208]

Though the combustion of hydrogen produces no carbon dioxide, the means by which the hydrogen itself is traditionally produced can emit greenhouse gases. The cheapest form of hydrogen, called 'gray hydrogen,' is produced from natural gas and emits the most carbon dioxide. When CCUS is applied to the gray hydrogen production process, 'blue hydrogen' is produced, which is more expensive. It adds 10 to 50 percent to wholesale production costs—but does significantly reduce the amount of carbon dioxide produced.[209] Finally, there is 'green hydrogen,' produced using renewable energy via electrolysis, which releases no emissions. Currently, green hydrogen adds 200 to 800 percent to wholesale production costs, but with the appropriate incentives and technology development, these costs can come down.[210] Alongside establishing these incentives and conducting R&D, in the interim, it may also be necessary to deploy hydrogen technologies that utilize gray or blue hydrogen in order to scale up hydrogen infrastructure and facilities. That would allow us to be ready to scale up green hydrogen when it becomes cost competitive.

Emerging breakthrough technologies

Novel materials have the potential to address some of the most challenging industrial emission sources. Scientists are continually developing new technologies that reduce emissions from concrete and even some that will allow concrete to store carbon dioxide—the key now is to reduce costs and prove the suitability of substitutes for all building needs. Other companies and researchers are developing processes that can capture carbon dioxide from power plant emissions to use in manufacturing building materials.[179,180] In Belgium, ArcelorMittal is collaborating with a new clean tech company, LanzaTech, to demonstrate that bacteria can convert emissions from steel plants into fuels and chemicals.[181] There are many opportunities for U.S. companies to develop—and commercialize—solutions for these industrial processes that are currently difficult to decarbonize. The federal government can be a powerful ally to these companies through targeted funding in basic and applied research and demonstration projects.

Developing natural and negative emissions technologies

Carbon capture, utilization, and storage (CCUS) is critical for industry in the long term, as alternative emission reduction options do not yet exist for many sources.[182] Carbon dioxide that is captured at industrial facilities can be stored long term or used to make other valuable products, resulting in a net reduction of greenhouse gas emissions to the atmosphere.[183] Some of these valuable products include construction materials, such as carbon dioxide-storing aggregates and binders used for concrete. Captured carbon dioxide could also be used as a feedstock for making non-petroleum based plastics with potential for biodegradability, and other environmental benefits beyond greenhouse gas emission reduction.[184] Fortunately, CCUS infrastructure developed for the electricity sector can be applied to industrial sources, generating benefits to both sectors. We need a national strategy that optimizes CCUS for both applications and provides research support for utilization technologies. Another option for achieving net-zero emissions economy-wide is to deploy negative emission technologies. Promising negative emission technologies include: afforestation projects and other natural solutions; direct air capture (pulling carbon dioxide directly from the air); and bioenergy with carbon capture and storage (BECCS), which pairs carbon capture technologies with biofuels.[185] All of these technologies require more research and development to deploy them at the scale needed, but we likely need to pursue all options to achieve a net-zero economy.

> "We need to call upon the cities and towns that built America to rebuild America. That helps every community, urban and rural, to invest in ourselves by creating a cleaner, more sustainable economy; to create a transition that allows all to share in the prosperity that can be created by jointly addressing the challenges of climate and inequality; to rebuild an America that uses wind turbines with American steel; to retrofit our buildings with American labor; and to deploy technologies that are developed in our colleges and university research labs."[202]
>
> **— William Peduto**
> *Mayor of Pittsburgh*

Federal policy must accelerate the clean industrial transition

To rapidly achieve a net-zero industrial sector, we will need to use all the federal policy tools available and invest significant government resources. Given that private markets tend to be risk-averse,[186] there is a necessary and proper role for direct federal support. The government must also guide the market to value emission reductions; it has several policy options at its disposal, including tax incentives, a price on carbon, emission regulations, and others.

Incentivizing broad deployment of clean technology solutions

INVESTMENTS AND TAX CREDITS. The American Recovery and Reinvestment Act (ARRA) of 2009—the stimulus bill that helped pull us out of the Great Recession—established the 48C manufacturing tax credit to foster investment and job creation in clean energy manufacturing. The credit was used by 183 domestic clean energy manufacturing facilities and valued at $2.3 billion.[187] A revived and redesigned 48C program could aid in retrofitting or offsetting emissions throughout the industrial sector by helping fund CCUS projects; direct air capture; combined heat and power or waste heat to power projects; and more. Other ARRA-era programs could also be revived and retooled to encourage clean manufacturing, including proposals related to Section 132 and Section 1603 grants. Congress could also update and extend the 45Q tax credit to incentivize the capture of unavoidable, process-based industrial carbon emissions.

FINANCING. The capital investments required to achieve deep decarbonization will not come cheap. Large-scale climate or green banks, industrial banks, revolving loan funds, and other tools can encourage and guide the necessary investments of private and public capital in industrial decarbonization. Federal investments should also encourage the development of domestic supply chains and manufacturing capabilities necessary for the United States to lead the world in clean technologies. Additionally, a more agile domestic manufacturing sector could increase resiliency of supply chains, an issue highlighted by the economic crisis brought on by the COVID-19 pandemic.[188]

MARKET SIGNALS. Nothing will focus the industrial sector on emission reductions quite as effectively as clear regulatory certainty and price signals designed to rapidly deliver economy-wide net-zero emissions. This can be accomplished through direct regulatory requirements, a cap-and-trade system, emission standards, or emissions taxes. But any and all options must be carefully designed to (1) ensure emission reduction targets are met, (2) address high-emissions goods coming into the country, and (3) ensure equity for all populations by addressing the needs of deindustrialized communities, protecting vulnerable populations from pollution, and providing jobs with good wages and benefits. A mix of approaches is likely needed. For example, an economy-wide carbon price alone may not be as effective for reducing emissions in this sector as it would be for the electrical sector. Due to the cost of available technologies, a carbon price—if implemented alone—would need to be quite high to drive deep emission reductions. Supporting policies like standards and regulatory requirements, when implemented with a reasonable carbon price, can help ensure the intended outcome of net-zero emissions.

Building necessary low-carbon infrastructure

A clean electric grid, hydrogen, and CCUS are all important low-carbon solutions, but each needs large-scale infrastructure for large-scale deployment. This includes transmission lines, pipelines, and storage, all of which are challenging to site and permit.[189] A single steel plant that wants to use hydrogen fuel in place of coal depends on robust hydrogen supply lines to make that transition feasible. To ensure rapid adoption of cleaner technologies, the federal government must help plan and fund the national infrastructure networks that industry will need.

RESPONSIBLE MINING AND RECYCLING

The federal government must pursue polices to ensure environmental, economic, and socially responsible mining of minerals on the front end of product development, and encourage recycling of materials at the end of their life. A key focus of federal R&D should be on designing processes and technologies that are easily disassembled and recycled.[203] In addition, the federal government should invest in and incentivize the development of responsible recycling industries focused on reclamation of critical minerals.

From the Iron Range in Minnesota to the coal mines in Appalachia to the gold, silver, and copper mines of the American West, mining is a culturally and economically important industry for many regions of the United States. A dramatic scale-up of today's clean technology across sectors will require both an increase in supply of critical minerals, such as lithium and rare earth elements, and the development of clean technology that uses alternative materials. Without advancements in technology or substitution, the demand for lithium, which is used in grid storage and electric vehicle batteries, is expected to increase fivefold by 2025.[204] The mining of these materials needs to be considered when designing a net-zero emissions future. For many critical minerals, the majority of global supply is provided by a single country, which leads to obvious concerns about supply chain stability and security.[205] For example, 70 percent of the world's cobalt is from the Democratic Republic of Congo and is mined without environmental or labor standards.[206] We cannot advance a clean future if we are building these technologies with materials mined in foreign countries in an unsafe and environmentally degrading way. Fortunately, there are examples of responsible mining to build from. For example, the Sibanye-Stillwater mine in Montana has modeled a successful Good Neighbor Agreement between the mine and local environmental concerns for 20 years.[207] The federal government should also help bring to market new technologies that can substitute cheap, abundant materials for expensive and rare minerals.

The lifetime of a mine is usually measured in decades, but the environmental impacts of a mine can last much longer. If not properly managed, problems from mine waste can persist for many years after closure—sometimes centuries. As we look to the future of mining, we cannot fail to address the more than a century of legacy mines that still cause problems today, particularly in the American West. The federal government must ensure that mining companies fund the cleanup of abandoned mines that continue to pollute waterways today by reforming the outdated Mining Law of 1872. Cleanup and reclamation of abandoned mines provides an opportunity for good-paying, union jobs in the impacted communities and sets the stage for the next phase of local economic development. A national commitment to responsible mining, reclamation, and recycling within the United States can provide supply chain security, create jobs, and support American industry and leadership while protecting the environment.

Driving change through federal purchasing

Market demand will help pull innovative, clean materials and goods from the laboratory into widespread use.[190] From roads to buildings and other large infrastructure projects, the federal government purchases many industrial materials. Experts estimate that federal, state, and city governments purchase 90 percent of cement and concrete and 50 percent of steel used in the United States.[191] Federal clean procurement standards, based on programs like the Buy Clean program currently enacted in California,[192] can create this demand. Similar programs are being explored in a number of other states, including Washington and Minnesota, and internationally.[193] National procurement standards could mandate that materials purchased using federal dollars or for use in federal projects do not exceed a specific threshold for the amount of carbon emissions released during their manufacturing process. By creating a market for clean products manufactured with high labor standards, procurement standards can help reduce industrial greenhouse gas emissions, support good American jobs, and drive down the cost of manufactured products for the American consumer.

Coupling federal investments with guarantees of worker and community benefits

When the federal government commits taxpayer resources—via loans, grants, tax credits, federal contracts, or federal procurement—it should maximize benefits to American workers and families. This should include, whenever possible, policies that support domestic production and manufacturing, high labor standards, Davis-Bacon prevailing wage provisions, support for workers' right to organize, local employment, worker training, and other community benefits. Policies must prioritize the health and safety of communities by enacting leading energy, emissions, and pollution standards, as well as advanced safety rules at facilities. Federal incentives are also needed to grow manufacturing in the United States that minimizes or replaces toxic chemicals and materials; we must increase jobs while safeguarding our communities from environmental harms.

Enforcing a level playing field for international trade

If we are going to demand our U.S. manufacturers reduce emissions and provide good jobs, the federal government must enforce a level playing field for international trade. Materials imported into the United States should be subject to the same emissions standards and carbon prices imposed on any domestic materials and should be held to high labor standards. Congress will need to consider border tax adjustments and other import controls to achieve this. American competitiveness must be a priority when considering climate actions; a net-zero economy can and must coexist with a growth in U.S. manufacturing.

Supporting robust RD&D for breakthrough technologies

The United States needs an innovation agenda that explicitly supports industrial decarbonization. Increased investment in research, development, and deployment (RD&D) needs to start now, because the time from lab-scale concept to commercial deployment can be decades. Programs like the Advanced Manufacturing Office at the Department of Energy (DOE) are ready to lead enhanced research portfolios. Solutions for the hardest-to-abate processes will likely arise from scientific and technological breakthroughs that haven't yet happened. Robust research funding will help ensure the United States leads in discovering and inventing those solutions.

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Many solutions have been shown to be technically feasible, but are not yet commercially viable. Programs like the DOE Loan Program Office should be used to support young companies and entrepreneurs as ideas move through the 'valley of death' between lab-scale validation of a technology and commercial deployment. Targeted federal support at this stage can help spur private investment by reducing some of the risk inherent in demonstration facilities and pilot projects.[194] Advances in wind and solar energy exemplify how federal support at this key stage can lead to dramatic price drops and greatly expanded deployment.

Several other federal programs already exist that can be scaled and modified to better address these needs, including the DOE Innovative Loan Guarantee and the Tribal Energy Loan Guarantee programs. Additionally, a broader manufacturing grant and loan program would both aid initial technology development and demonstration and provide a means to encourage wide-scale use of emission reduction technologies. Congress could also create new retooling and technology conversion loan programs to quickly scale low- or no-emission industrial technologies and clean manufacturing capabilities at existing facilities.[195]

Organized Labor Priorities

Decarbonization of the U.S. economy is not only a technical challenge, but also a human one. The United States has a strong history of quickly developing and deploying technology and infrastructure when needed. But without the right policies in place, technological advancement has not always led to high-quality jobs. The success of the transition will hinge on how well it works for people, both as consumers and workers. Our actions to decarbonize our economy must ensure that the jobs created in the transition are good, stable, high-paying jobs that support American workers, their families, and their communities.

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Specifically, the transition cannot come at the price of unionized careers. Labor unions are critical to creating high-quality jobs, because as decades of research demonstrate, labor unions increase workers' wages, reduce income inequality, raise labor standards, and even boost wages for nonunion workers.[211] Due to the collective action of workers and unions, jobs in fossil fuels have historically been high-paying and unionized jobs. Coal and natural gas electric generation workers have 10 and 11 percent unionization rates, respectively—almost double the national average.[212] This stands in contrast to the current renewable energy sector. While renewables employ more workers than nuclear and fossil fuels, these jobs are typically less unionized and employ more contractors. This often means workers are paid less and may lack a voice at work or receive the same worker protections. Additionally, the percentage of union jobs has been decreasing in the industrial sector for decades—a trend that must be reversed.

Federal investment in the clean energy economy will create millions of jobs in manufacturing, construction, and operations. Congress has the power—and the duty—to pass policies that support all workers and protect workers' right to organize to ensure good pay, benefits, and working conditions. Policies to address decarbonization need to promote the right to organize, prevailing wage standards, strong health and safety standards, and other pro-worker polices wherever possible.

The transition will impact some regions more than others. But workers should not be forced to abandon the homes and neighborhoods they have known for decades in order to find jobs. Decarbonization must create opportunities in every region. To do this, we must be prepared to financially support states and counties in transition and provide job training and education opportunities to workers. We must also make targeted investments to rebuild these economies based on low-carbon industries.

The Special Committee sought input and recommendations from unions and other labor organizations through meetings, hearings, and a solicitation for written input. Below is a summary of what we heard.

Organized labor's input to the Special Committee

- **Enforce prevailing wage requirements and increase labor standards and protections for all workers.** Workers continue to experience stagnating wages and challenging working conditions due to declines in unionization and a fundamental shift in how companies value their workers across industries nationwide. In order to improve conditions for all workers, Congress should encourage higher wages and benefits so workers can support their families. Congress has the opportunity to include pro-worker provisions in climate and energy policies, like eliminating barriers to organizing, improving worker classification, and discouraging temporary labor.

- **Prioritize American workers.** Legislation must incorporate Buy America/n and Davis-Bacon requirements to protect American workers amid a global race to dominate the clean energy economy.

- **Tie federal assistance to pro-labor policies.** Federal grant programs, tax incentives, and other measures aimed at aiding the energy transition should explicitly prohibit anti-union activities as a condition of receiving federal assistance.

- **Invest in developing new economic opportunities for communities impacted by deindustrialization and decarbonization.** A mix of federal investments and incentives can help grow new clean manufacturing and industrial companies, and with them, jobs. These investment should specifically target new economic opportunities in places suffering from past deindustrialization and those impacted by decarbonization, as well as low-income communities and communities of color.

- **Conduct further macroeconomic analysis on net-zero greenhouse gas policies to better understand impacts on the U.S. economy and American workers.** Decarbonization will affect some regions and workers more than others. In order to develop a better understanding of who those individuals are and the extent of the impacts, we must conduct more in-depth analyses of proposed policies to better understand—and be able to prevent—economic disruption and market uncertainties.

- **Increase funding to new energy technology demonstration and deployment projects.** To further drive down costs in new energy technologies (like carbon capture, utilization and storage; small modular reactors; and hydrogen fuel), federal investment should help offset high initial costs.

- **Increase public and private sector investment in upgrading infrastructure.** By improving energy infrastructure, and public infrastructure more broadly, communities will be more resilient to future climate-induced disasters while creating jobs.

- **Develop an energy transition fund.** Significant funding is needed to support workers and their families. These funds could go towards lost wage compensation, retraining, and education opportunities. Additionally, the funds could be used for community redevelopment and helping local governments replace lost tax bases to ensure the continuity of vital public services.

- **Develop and enforce industrial performance standards and fair trade rules that will allow the United States to compete with international markets while protecting workers.** By increasing performance standards and enforcing fair trade rules in high-emitting industrial sectors like steel, aluminum, paper, chemicals, and petrochemicals, the United States will reduce the risk of losing industrial jobs to lower-cost international competition or allowing businesses to outsource work. Such standards should not only be developed and implemented through the EPA and Departments of State and Commerce, but also in coordination with the United States Trade Representative, in order to establish global standards.

- **Improve retraining and education opportunities for displaced workers and underrepresented communities**. Union apprenticeship programs have proven successful at training workers in a learning-while-earning model. Registered apprenticeships, union training centers, and community colleges should be expanded and financially supported to help meet demand for a well-trained clean energy workforce. These opportunities should be concentrated in low-income and underrepresented communities to help provide a pipeline to quality, durable employment.

- **Embrace legislation with an "all of the above" approach.** Reducing emissions across all sectors of our economy will require a diversity of technologies. Future legislation should encourage innovation and drive the most cost-effective emissions reduction solutions, rather than favoring some technologies over others.

- **Strengthen American manufacturing and supply chains.** Expanding domestic supply chains and manufacturing will not only create jobs, but also increase access to the sustainable products and materials that are necessary for a clean energy transition. This will require investments in advanced manufacturing and R&D.

TRANSPORTATION

> Rapid increases in zero-emission vehicles, cleaner liquid fuels, public transportation, and smarter planning can significantly reduce emissions from the transportation sector. Research and innovation will be essential to achieving full decarbonization.

Americans rely on our transportation system to safely, efficiently, and equitably move people and goods. In the face of the climate crisis, it is more important than ever that we also do this cleanly. The methods we use to get people and things where they need to go varies widely throughout the country, so our decarbonization solutions need to be flexible and scalable. Overall, we need to significantly increase clean options that work within peoples' daily lives. Doing so will have compounding benefits throughout the economy and society, including preventing air pollution, reducing health costs, saving people time and money, and addressing longstanding inequities.

The transportation sector has been the largest source of greenhouse gas emissions in the United States for the last four years, accounting for 28 percent of total emissions in 2018.[213] These emissions have risen every year since 2012, and they are rising faster than any other segment of the economy.[214] We need to rapidly reverse this trend. Besides carbon pollution, transportation is also a major source of other toxic air pollution—in 2015, transportation emissions led to 22,000 deaths in our country and 385,000 globally.[215]

In urban and suburban communities, better community planning and drastically scaled investments in transportation alternatives can allow people to get to where they work, shop, and play without having to drive. Almost half of all vehicle trips in the United States are less than three miles long[216]—so with the right investments and smarter planning, walking, biking, and transit can be safe and efficient alternatives to driving in many parts of the country. Aside from the significant climate benefits, transportation alternatives will help promote individual health and ensure clean air in our neighborhoods. Public transit is also important in rural areas, where it supports economic development and accessibility for the elderly and disabled. But we need additional solutions to decarbonize the transportation sector in rural areas where driving is a fact of life.

The United States currently has over 270 million registered vehicles,[217] and our cars, trucks, and SUVs account for almost 60 percent of emissions within the sector.[218] Scalable solutions to make vehicles cleaner can play a significant role in getting us to a global net-zero emission economy by 2050. In part, this requires stronger emissions standards for cars and trucks and new policies to bring cost-competitive advanced liquid fuels to market.

Most importantly, we need to rapidly increase the share of zero-emission vehicles (ZEVs) on our roads, along with the infrastructure to power them. The cost of ZEVs is decreasing, making them an economical choice for millions of Americans. New policies and incentives can help continue driving ZEV costs down for consumers and making them accessible to even more Americans. Building our country's ZEV infrastructure will not only create quality jobs, it will also provide millions more Americans the opportunity to save money and protect them from the price fluctuations of the gasoline market.

We also need to decarbonize our long-distance transit and shipping methods. Electrification and low-carbon liquid fuels will play a particularly important role in addressing emissions from trains, ports, and freight segments.[219] And we will need to develop new technologies to address modes that are currently hard to decarbonize, like aviation and shipping.

The federal government can support these goals by:

- ✔ Funding locally driven smart growth planning and public transit.
- ✔ Ensuring stronger vehicle emissions standards.
- ✔ Establishing a national ZEV standard, increasing access to ZEVs through incentives, and investing in ZEV infrastructure.
- ✔ Increasing federal grant programs and direct investment to make public vehicle fleets and school buses zero emission.
- ✔ Increasing federal transportation funding for infrastructure that will lower emissions.
- ✔ Supporting R&D to create the next generation of liquid fuels.
- ✔ Incentivizing electrification of shipping and rail, and building out U.S. high-speed rail.
- ✔ Ambitiously regulating aviation emissions and increasing federal R&D spending on usable batteries and advanced fuels for aviation.

We can reduce transportation emissions while strengthening the U.S. economy and improving our quality of life. Other nations are racing to develop technologies to decarbonize their transportation sectors, and the United States cannot afford to miss the opportunity to compete for market share in the burgeoning clean transportation industry. The U.S. economy has always thrived on ingenuity, and this transition affords the opportunity to substantially grow our manufacturing economy and create high-quality jobs. Realizing this vision will require policies that build out the entire manufacturing chain within the United States.

Increasing clean transportation options reduces emissions and can address transportation inequities

Rethinking our communities to enable Americans to choose walking, biking, or public transportation over driving can significantly reduce emissions, especially in urban and suburban areas. Unfortunately, conventional U.S. urban planning has long artificially restricted the number of housing units built near commercial centers and transit corridors. Local zoning laws generally concentrate jobs in urban areas or suburban office parks, while restricting housing to residential-only neighborhoods.[220] Many communities have effectively banned affordable multi-family housing near job centers and public transit, zoning those areas only for single-family homes. In doing so, they have forced low- and moderate-income commuters to make long drives from suburbs and exurbs, exacerbating traffic and congestion for everyone.[221] Restrictive zoning has led directly to the epidemic of automobile-centric "sprawl," as well as maintaining or even increasing racial segregation in our communities.[222]

> We know that investing in public transit [raises] property values, making [the surrounding area] more susceptible to zoning. […] That's why we believe in working hand in hand with the transit agency…to [develop] anti-displacement programs that allow community-based organizations to organize residents ahead of time, to be able to have self-determination in asking for what are the services and needs that they have around those investments. That has to be paired together."[289]
>
> **—Vivian Satterfield**
> *Director of strategic partnerships, Verde*

Increasing urban density can be a potent tool to reduce emissions. Done right, it can also help address critical issues of equity and housing affordability. Models consistently show that dense urban neighborhoods with low carbon footprints are anchored by both affordable housing and transit access.[223] Concentrated development, or "smart growth," therefore requires changes to land use and zoning laws that allow for mixed use and residential density, as well as policies that expand public transit. Putting homes, offices, and necessities like grocery stores and restaurants in close proximity can allow cities to continue growing while slashing vehicle miles traveled.[224]

Public transportation is also a powerful tool to reduce emissions. Even in less dense communities, trips on public transportation result in significantly fewer emissions than comparable trips in personal automobiles. Emission reductions from public transportation can be measured in two distinct categories: emissions avoided by shifting modes from less efficient private automobiles to more efficient transit trips, and emissions avoided when transit enables denser land-use patterns.[225] Longstanding research shows that trips on heavy rail transit, such as subways and metros, produces 76 percent fewer greenhouse gas emissions per passenger mile than an average single-occupancy vehicle trip. Traditional diesel bus transit produces 33 percent fewer emissions

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when partially filled, but emission savings can increases to 82 percent when the bus is at full occupancy.[226] Even greater emission savings can be achieved when zero-emission buses are deployed.

The emissions gains we currently realize from our existing public transportation, however, cannot be taken for granted. Decayed infrastructure, outdated vehicles, and chronic budget shortfalls threaten the ability of many U.S. transit systems to retain and attract riders to their services. Transit ridership has declined slightly in recent years, with many factors likely contributing, including low gas prices, the rise of ridesharing, and increasing telecommuting—but the diminished quality and reliability of transit services are key factors. Systemic underinvestment in public transportation has saddled U.S. transit systems with a $99 billion backlog of repairs, and reliability issues caused by decades of neglect have clearly hurt ridership.[227]

Before the COVID-19 crisis, evidence was emerging that when transit agencies, like those in New York City and Washington, DC, improve the reliability and quality of their service, ridership growth resumes.[228] To further increase emission reductions generated by public transportation, communities must build and expand high-frequency and high-capacity services like rail systems and bus rapid transit to attract new riders.

Combining density with public transportation amplifies the gains that can be achieved by each individually. DOT's Federal Transit Administration has the Pilot Program for Transit-Oriented Development (TOD) Planning, which provides small grants to local communities to integrate land use, real estate development, and transportation planning around new high-capacity transit services. These programs can be used to support more communities as they develop toward a more resilient future.

Beyond transit planning, the Environmental Protection Agency (EPA) produced 11 smart growth "essential fixes" for communities whose zoning rules presented barriers to meaningful change. The fixes vary from "modest adjustments" to "wholesale changes," allowing communities to tailor solutions to fit their political situations, financial resources, and organizational capacities.[229] From mixed-use zoning and improved parking standards, to walkability and storm water management improvements, these principles provide a roadmap for communities to build more diverse, resilient, and climate-friendly communities.[230]

One of the primary objectives of smart growth is to enable people to walk safely and easily to work, school, stores, houses of worship, and parks. Many U.S. roads are designed to move vehicles at the highest speeds possible, with little consideration for walking, biking, or transit.[231] Currently, many local codes discourage walking by prioritizing low-density designs and landscapes designed for cars instead of people. Communities must stop treating pedestrians as an afterthought. Aside from their climate mitigation benefits, walkable neighborhoods improve quality of life, foster economic development, and result in safer and more attractive urban environments.

Cities can modernize their street planning by adopting a "complete streets" approach: a multimodal design that provides equally safe and accessible options for pedestrians, bicycles, personal vehicles, and transit.[232] This concept is already underway in the United States—for example, the Massachusetts Department of Transportation implemented a "Complete Streets Funding Program" to provide municipalities with technical assistance and construction funding to plan and rebuild their streets.[233] Another key benefit of smart urban planning is more housing choices for people of all incomes. Flexible zoning requirements and denser development can incentivize construction of affordable housing, providing the foundation for more diverse and vibrant communities.[234]

For rural and agricultural communities at the edge of urban expansion, the desire to grow an economy may appear incompatible with maintaining local character. However, similar changes to planning and zoning can benefit rural communities just as much as urban ones. For example, mixed-use development on Main Streets can leverage historically significant architecture and valuable public spaces and reduce the risk that these local assets are forsaken in favor of office parks and regional malls.[235] Small towns may have fewer resources to implement smart growth than urban and suburban areas—but the EPA has also published a comprehensive list of policy options to help rural communities pursue fiscally sound, climate-smart, equitable growth.[236]

All community development strategies should be formulated with extensive local input. And smart growth must not come at the expense of established, lower-income urban and rural communities. Well-intentioned urban planning would ultimately achieve little if it exacerbated inequities and accelerated gentrification.

Transportation inequities are the result of decades of policy choices that have directed resources to some communities and away from others. These policy choices have real impacts on people's lives: transportation access has been linked to higher employment and better health outcomes.[237]

These decisions affect both safety and access. For example, a pedestrian in East Portland, Oregon, which has a high concentration of communities of color, low-income households, and communities with limited English proficiency, is twice as likely to be killed in a traffic crash as pedestrians in the rest of Portland.[238] Further, nonwhite commuters make up 60 percent of public transportation riders,[239] underscoring the importance of efficient transit access for communities of color. Improvements in access to public transportation and other clean transportation options can significantly improve mobility and increase economic opportunity for many disadvantaged and low-income communities.

Investment in sustainable and zero-emission transportation needs to achieve mobility for all Americans, including low-wealth and rural populations, people with disabilities, and communities of color. Many Americans cannot afford to own cars and trucks and lack access to affordable and safe public transportation options. The federal government needs to provide significant new funding and financing to promote smart growth, safer streets, and public transportation options. All funds should be spent with a focus on addressing the transportation inequality that still exists today.

Cars and trucks provide a significant opportunity to reduce emissions

One of the biggest steps we can take immediately to combat climate change is making our cars and trucks cleaner. We have multiple policy options to improve efficiency in existing vehicles and significantly expand the use of zero-emission vehicles.

Improving emissions standards

EPA pollution standards for cars and trucks,[i] first implemented in the 1970s, have drastically reduced smog and saved thousands of lives.[240] Following a 2007 Supreme Court ruling in *Massachusetts v. EPA* and EPA's 2009 finding that greenhouse gases endanger human health and welfare, EPA vehicle standards also covered greenhouse gas emissions. In 2012, EPA and the National Highway Transportation Safety Administration (NHTSA) jointly updated their vehicle greenhouse gas and fuel economy standards for light-duty vehicles for model years 2017-2025. The standards were projected to reduce greenhouse gas emissions by 2 billion metric tons over the life of the program[241] and save Americans hundreds of billions of dollars. It was the most significant federal action ever taken to reduce climate pollution and improve the fuel economy of light-duty vehicles. In 2020, President Trump's EPA and NHTSA reversed course on the standards and finalized a new rule that dramatically weakens the existing standards.[242] The administration moved ahead with this action even though its own analysis concluded the rollback would cost jobs and lead to increased premature deaths.

President Trump has also moved to prevent states from implementing ambitious clean car standards of their own. California had standards in place to address vehicle emissions when the Clean Air Act passed, so Congress deliberately maintained California's authority to set its own standards—provided they were at least as strong as the federal standards and the state obtained a waiver under the Clean Air Act. Other states are also permitted to adopt California's standards, and several have done so: Connecticut, Colorado, Delaware, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington, as well as Washington, DC.[243] Minnesota,[244] New Mexico,[245] and Nevada[246] have also recently announced their intentions to adopt the standards. EPA granted a preemption waiver for stronger state climate pollution standards in 2009. However, in 2019 the Trump administration revoked California's waiver and simultaneously claimed that the Department of Transportation's fuel economy authority preempts state clean car standards, even though the CAA provides no mechanism for revoking such a waiver and no waiver had ever been revoked before. This attack on states' authority to protect their own residents was opposed not only by California, but also by many of the auto manufacturers the rollback was purported to benefit.[247] The administration's action is being challenged in federal court by 24 states, the District of Columbia, and the cities of Los Angeles and New York.[248]

i EPA pollution standards are implemented under the Clean Air Act (CAA); National Highway Traffic Safety Administration (NHTSA) fuel economy standards are implemented under the Energy Policy and Conservation Act.

To achieve meaningful emission reductions for car and trucks, a new generation of clean car standards is needed. Such standards will reduce pollution while saving Americans money and spurring leadership and innovation from U.S. auto manufacturers. Congress should direct the EPA to use its existing Clean Air Act authority to set ambitious new greenhouse gas emission standards and direct NHTSA to use its Energy Policy and Conservation Act authority to set ambitious new corporate average fuel economy standards. It is also important that states retain the ability to protect their citizens by adopting more stringent car standards.

Rapidly expanding the use of zero-emission vehicles

ZEVs will be cost competitive in the very near term, and some models already are. They can immediately save drivers money and protect them from the volatility of gasoline prices. ZEVs are an even more compelling choice when considering the benefits of avoided climate impacts and improved public health. Replacing internal combustion engine vehicles with ZEVs will reduce co-pollutants, including particulate matter, nitrogen oxides (NOx), and other chemicals responsible for smog and respiratory disease, which will save thousands of lives. A recent study suggests that a complete conversion to electric vehicles by 2040 in the city of Houston alone would save more than 220 lives, $2 billion, prevent 24,650 asthma attacks, and avoid over 18,000 days of missed school annually.[249]

Eleven states and the District of Columbia already have ZEV regulations that require auto manufacturers to offer a defined numbers of electric, hydrogen fuel cell, and plug-in hybrid vehicles. These standards have played an important role in expanding the market for ZEVs. They have created an incentive to build out charging infrastructure and ultimately contributed to the availability of over 40 ZEV models in the United States in 2019.[250] A study by the American Lung Association found that in a scenario where the first 10 states (Colorado has since adopted the standard) that adopted ZEV standards went to 100 percent ZEVs by 2050, they would "experience over $33 billion in health and climate savings in 2050, avoid 195,000 lost work days, and prevent over 96,000 asthma attacks and over 2,200 premature deaths."[251] An ambitious national ZEV standard would be the most impactful policy to achieve this vision in every state.

> "Clean transportation technology is critical to addressing climate change and making our air healthier; it can strengthen our economy while supporting millions of high-quality jobs; and it can help unravel many decades of inequitable transportation investments and policy."[301]
>
> **— Jeff Allen**
> *Executive director, Forth*

Transitioning to ZEVs presents an opportunity to invest in American entrepreneurship and infrastructure while supporting working families and frontline communities. Iconic American companies like Ford, General Motors, and Tesla are leading the way on ZEVs, while Honda recently announced plans to manufacture ZEVs at plants in North America. Critically, many of the policy mechanisms necessary to electrify the American transportation system already exist or have been proposed by lawmakers.

ZEV TAX CREDITS. One of the primary drivers of electric vehicle adoption in the United States has been the Electric Vehicle Tax Credit. The credit provides the buyer of an EV a federal income tax credit of up to $7,500. Under current law, the credit begins phasing out when a manufacturer sells 200,000 EVs.[252] Already, two carmakers have hit the 200,000 vehicle cap.[253] The credit has succeeded in helping establish a market for electric vehicles. However, it is now creating a perverse system in which the American companies that took the risk to be early movers on EV technology—and helped bring down costs across the market—are now at a competitive disadvantage to later entrants. The expiration of the credit for some manufacturers is coming just as EVs are approaching cost parity with internal combustion engine vehicles. Reforming this credit would level the playing field between manufacturers and help make electric vehicles an affordable choice for more Americans. If this credit is not extended, it will put domestic car manufacturers at a disadvantage to their foreign competitors for this important, and growing, segment of the market.

CONSUMER INCENTIVES. Less expensive ZEVs are breaking into the market, but the upfront cost of these vehicles and access to infrastructure remains a barrier for many middle- and low-income families looking to making cleaner choices in their vehicle. One drawback of tax incentives is that they are less useful to consumers who do not have a significant tax bill or cannot wait until the end of the year to get their credit. Direct consumer payments, especial for low-income ZEV buyers, can help a wider range of Americans choose a cleaner option now.

The pace of clean vehicle adoption will have reverberations for a decade or more. The average age of a vehicle in the United States is roughly 12 years, and the average vehicle lifetime is just over 16 years.[254,255] It takes almost two decades for new technologies to be fully integrated into the vehicle fleet, so it is essential to make progress now and speed fleet turnover to avoid missing out on pollution benefits for decades to come.[256] A proven way to turn over the fleet faster is by giving consumers a financial incentive to replace their vehicles with new, cleaner, and more efficient ones. In June 2009, Congress passed the Car Allowance Rebate System (CARS) Act. CARS created a temporary “cash for clunkers” program that provided Americans with a credit of up to $4,500 to trade in their car for a new model. The program used about $3 billion to retire over 677,000 inefficient cars and helped stimulate the economy, save American jobs, and reduce oil consumption. Similarly structured, new programs could expedite the transition of America’s automobile fleet by making ZEVs affordable for everyone. To drive a faster turnover of the U.S. car fleet and achieve deeper carbon reductions, Congress should create new cash inventive measures—focused on exchanging cars with internal combustion engines for ZEVs. And a premium should be placed on supporting U.S.-based manufacturing and jobs.

RESEARCH. The United States must continue prioritizing research, design, and development funding to further drive down the cost of ZEVs. There are several programs within the Department of Energy (DOE) aimed at speeding up the development of electric vehicles, and they should all be funded. One program that has proven effective is Advanced Technologies Vehicle Manufacturing (ATVM). Electric vehicle leaders Ford, Nissan, and Tesla have all received significant support through ATVM. Congress created the ATVM loan program in

2007 as part of the Energy Independence and Security Act (EISA); it provided DOE with $25 billion in loan authority to speed up the development of vehicles that increase fuel efficiency. The program has made $8 billion in loans that have supported the production of over 4 million electric vehicles. The ATVM program has $17 billion in authority remaining—but despite the program's record of success, and a backlog of applicants hoping to access it,[257] the Trump administration has repeatedly proposed repurposing the program's funding in its budget.

ZEV INFRASTRUCTURE INVESTMENTS. An important step to support widespread adoption of ZEVs is improving the infrastructure they require. Congress can promote the rapid expansion of ZEV infrastructure through incentives, direct investments, and the removal of current barriers to installation.

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Greater access to charging infrastructure is particularly needed for rural Americans and urban Americans without a garage or parking spot. To date, only a few companies have invested in charging stations, and the federal government has not made electric vehicle charging a major infrastructure priority. The Department of Energy estimates there are only 78,000 charging outlets at fewer than 25,000 electric vehicle charging stations throughout the country.[258] A report by the International Council on Clean Transportation (ICCT) found that the United States will need to increase workplace and public fast-charging stations in metro areas by 400 percent in the next five years to service the electric vehicles projected to be on the road by 2025.[259]

The federal government can play an important role in expanding this infrastructure by building public charging stations at the property that it owns and operates, like post offices, courthouses, and other federal buildings. This approach is particularly helpful in bringing charging infrastructure to rural communities. The federal government owns about 270,000 buildings,[260] and adding charging stations to this existing infrastructure could play an important role in broadening access to ZEVs.

Projects like the West Coast Electric Highway, which has an electric charging station every 25 to 50 miles along major roadways in British Columbia, Washington, Oregon, and California, are important steps.[261] And other states are making similar investments. For example, West Virginia has installed charging stations at nine of its state parks free to visitors as a way to attract additional tourism dollars. But the federal government needs to make much larger investments to ensure all Americans have access to the infrastructure necessary for EV ownership. The Federal Highway Administration

currently designates alternative fuel corridors, a national network of alternative fueling and charging infrastructure along national highway system corridors. Congress should build off this strategic scheme and enact legislation to provide funding for ZEV infrastructure along designated corridors nationwide.

Financial incentives for building out ZEV fueling infrastructure need to be maintained and expanded. The tax credit of up to $1,000 for the installation of a home charger expired for two years before Congress extended it retroactively. Unless Congress steps in again, the credit is set to expire at the end of 2020. Additionally, the cap of $30,000 per property for businesses serves as a deterrent for many businesses that would otherwise add additional charging infrastructure.

Unfortunately, some of the barriers to building ZEV infrastructure are coming from the federal government itself. With limited exceptions, the Federal Highway Administration bans the construction of electric charging stations that require payment at public rest areas across the country.[262] As a result, states that want to install charging infrastructure are forced to provide the electricity free of charge, which makes their installation and maintenance cost prohibitive. This is an unnecessary barrier to the creation of a sustainable electric vehicle infrastructure along our highways.

Promoting the use of zero-emission vehicles in government fleets

Transitioning the nation's bus systems to ZEVs is an opportunity for the federal government to support a widespread, high-impact transition to battery electric and hydrogen fuel cell electric vehicles. The Federal Transit Administration's Low or No Emission Program is a grant program that provides transit agencies the funds to purchase or lease low- or no-emission vehicles and convert their fleets.[263] Expanding this program would be an important step in reducing emissions from the American transportation system.

As of last fall, 2,184 battery electric buses and 71 hydrogen fuel cell buses are already in operation nationwide.[264] These early deployments are providing valuable insight into future strategies to fully convert bus fleets to zero-emission technology. For example, many current battery-electric buses do not have the range to provide more than 200 miles of service under normal operating condition without recharging, so many agencies are utilizing in-route charging stations. Fuel cell buses are already capable of delivering 250 miles of service without refueling, but hydrogen fueling infrastructure is less common and agencies are working to achieve scale in fuel cell deployments to ensure the availability of reliable, low-cost fueling.[265]

In 2018, California required its public transportation agencies to convert their entire bus fleets to zero emission technology by 2040; by 2029, all bus purchases in the state will be battery electric or fuel cell electric. Transit agencies operate approximately 12,000 buses in California, and the California Air Resources Board estimates that the

transition of the state's bus fleet to zero-emission technology will be the equivalent of taking four million cars off the road.[266]

Converting school bus fleets is another avenue for significant ZEV adoption. School buses primarily travel a set distance daily, and districts can maintain their own fueling infrastructure, making these bus fleets a perfect candidate for electrification. Getting students away from tailpipe emissions and into cleaner alternatives provides significant public health benefits. The School Bus Rebate Program, part of the Diesel Emissions Reductions Act, offers school districts rebates to transition from diesel buses to cleaner alternatives. The federal government should provide additional funds for school districts to replace their fleets with ZEVs. Funding should benefit all schools and ensure that not only wealthy districts are able to take advantage of the advantages provided by ZEVs.

Transit agencies and school districts are not the only public agencies that own and operate large fleets. The federal government operates numerous sizeable fleets of vehicles, including within the United States Postal Service and the Department of Defense. The federal fleet is an obvious place where federal dollars could produce a significant transition to ZEVs that would ultimately benefit taxpayers. Congress should also expand the Federal Energy Management Program's Energy Savings Performance Contracts program to include vehicle fleets, so public agencies can benefit from ZEVs with no up-front capital costs. Congress should consider a ZEV standard for federal fleets, similar to how prior energy legislation included clean energy targets for federal agencies.

EV MANUFACTURING AND JOBS

In the United States, EV sales jumped from 275,000 in 2010 to 705,000 in 2018.[290] As the global demand for EVs increases, the United States has an immense opportunity to grow domestic EV manufacturing, along with the needed supply chains and infrastructure, and to create good-paying, quality jobs nationwide in the process. One study estimates that significant adoption of plug-in electric vehicles will generate about 50,000 additional jobs per year.[291] Building domestic EV supply chains will help the country rejuvenate its manufacturing sector and compete internationally in EV technology development and production. It will also enable us to ensure these jobs have strong labor standards and offer family-sustaining wages.

EV industry jobs extend beyond battery manufacturing, vehicle assembly, and vehicle maintenance. They also include charging device manufacturing and installation. As more EVs take to the road, more charging stations will need to be deployed along roadways and in homes and businesses throughout the country.[292] The United States currently has 20,000 public EV charging stations—yet in just the 100 largest cities, another 100,000 are likely needed.[293] Including other communities and personal residences, building out this infrastructure will provide the opportunity for many jobs. At a time when job creation is pivotal, producing EVs and installing charging infrastructure will help Americans get back to work.

Developing cleaner liquid fuels

Alternative liquid fuels could play a significant role in reducing the carbon intensity of the U.S. transportation system by transitioning it away from oil dependency. This is particularly applicable for medium- and heavy-duty vehicles, including trucks, farming and mining vehicles that are more challenging to electrify, and for specific regions of the country. It is also true for transportation modes like aviation, rail, some freight trucking, and marine shipping, where viable alternatives to liquid fuel are not yet available. It will also be important for the United States' existing fleet of internal combustion engine vehicles. Advanced and cellulosic biofuels, coupled with carbon capture and storage technologies, have the potential to serve as alternatives to fossil fuels if we continue investing in their development.

One of the big drivers of biofuels in the United States has been tax subsidies. In December 2019, Congress retroactively extended the biodiesel tax credit for years 2017-2022 and the second generation biofuels tax credit for years 2017-2020. The Joint Committee on Taxation estimated the value of the biodiesel tax credit at $15 billion and the second-generation biofuels tax credit at $43 million.

Currently, the primary driver of alternatives fuels in the United States is the Renewable Fuel Standard (RFS). The RFS creates a mandate for volumes of renewable fuels that refiners and blenders must use in transportation fuels, and sets up a trading system so those volumes can be used most efficiently. If implemented properly, the RFS gives farmers revenue stability, allowing U.S. agriculture to play an important role in reducing U.S. oil usage and further supporting rural economies. Although biodiesel use has expanded, the advanced biofuels segment has not otherwise developed as rapidly as the authors of the RFS envisioned. This is at least in part because the Trump administration continues to lower biofuel volumes and waive blending requirements under the RFS, jeopardizing the market stability that the RFS was intended to create. New policy tools may be needed to encourage growth of new advanced fuels beyond just corn starch ethanol and soybean biodiesel.

A Low Carbon Fuel Standard (LCFS) may also be an effective policy to reduce the carbon intensity of the fuel supply. An LCFS sets a maximum carbon intensity level for fuels that must be met each year, with the goal of increasing the range of commercially available low-carbon and renewable fuel alternatives.[267]

California was the first state in the country to implement an LCFS. The California system regulates refineries and distributors and allows emissions trading to increase economic efficiency. To date, California's LCFS has helped avoid 38 million tons of carbon pollution and the use of 13.7 billion gallons of gasoline. The California LCFS was the model for a similar program in British Columbia, and Oregon recently followed California's lead and adopted an LCFS of its own. In 2010, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and the District of Columbia formed the Transportation and Climate Initiative (TCI). TCI has developed a draft memorandum to create a cap-and-trade system for greenhouse gas emissions from transportation fuels and invest revenues to achieve additional emission reduction benefits. The proposal is currently out for public comment, and TCI hopes to finalize it by September 2020.

Low-carbon priorities should inform future transportation infrastructure spending

For decades, our country has spent billions of dollars to expand the national highway system while allowing a huge backlog of deferred maintenance on our roads, rails, and bridges. Between 1993 and 2017, the United States added 42 percent more freeway lanes in the 100 most urbanized areas—but this has done nothing to slow congestion.[268] Some studies have found that expanding highway infrastructure actually leads to increased congestion.[269] Despite the backlog of deferred maintenance, Highway Trust Fund (HTF) dollars continue to go overwhelmingly to building more highways—highways that will require maintenance in the future.

We need to invest in infrastructure maintenance to increase safety, reduce congestion, and improve access to communities of color, and rethink our transportation spending priorities. Currently, only 12-15 percent of money collected by the HTF goes into the account for mass transit,[270] leaving cities and transit agencies to address their crumbling transit infrastructure with limited local dollars. The United Sates must also begin building new high-capacity transit lines to attract future generations of riders. Accelerated investment in the construction and expansion of rail lines and bus rapid transit systems under the Federal Transit Administration's Capital Investment Grant (CIG) program could both attract riders and propel smart growth development in communities nationwide. There are currently more than 50 major projects across the nation seeking a CIG construction grant, but the number of applications might double or triple with more funding and reduced local matching requirements.

RETHINKING MOBILITY IN PORTLAND

Mayor Ted Wheeler of Portland, Oregon, told the Special Committee about the aggressive action his city is taking to fight climate change, while simultaneously building a healthier community. Portland has been able to reduce its per-person emissions by 38 percent in recent years, an important step in managing the city's carbon footprint given its fast growth and economic development. The city has undertaken projects to reduce the number of miles people have to travel per day and to make the miles people do have to drive less carbon intensive.

The Central City in Motion initiative improves public transportation options and establishes more protected bike lanes to encourage more biking.[294] The Portland Bureau of Transportation also recently expanded its bikeshare system, sponsored by Lyft and Nike, to include 1,500 pedal-assisted electric bikes by September 2020.[295] The city continues to expand its public options for EV charging[296] in its SmartPark public parking garages,[297] which offer motorists affordable, conveniently located parking with charging capability. People can also test drive a variety of EVs at Forth Mobility's premier EV showcase in downtown Portland, where the nonprofit helps potential EV owners envision a life in which they own, charge, drive, and plan trips in an EV.[298] Given this focus on transportation electrification and supporting infrastructure, Portland has become one of the leading cities in the United States for EV use.[299]

The United States needs to reshape its approach to public transportation by recognizing the value it provides. We need to treat public transportation as a public good that provides people with real benefits, including climate benefits—rather than a system that subsists on meager funding—if we want to achieve a carbon neutral transportation system. Significant new federal spending should be dedicated to affordable public transportation. That spending would have the added benefit of creating thousands of new jobs across the country.

Congestion relief programs have proven effective at helping states and Metropolitan Planning Organizations (MPOs) transition away from a reliance on single-occupancy vehicles and toward a more sustainable, climate-friendly transportation system by implementing measures like tolling, carpooling, commuter busing, non-highway travel, and travel during non-peak hours. The federal government should continue to find ways to efficiently utilize federal funding to scale congestion relief measures, while including mitigation measures for low-income drivers and those who lack easy access to alternative modes of transportation.

Existing formula apportionments should increasingly be directed to carbon reduction projects. These formula grants should be combined with competitive grant programs that give preference to states or MPOs that have seen emissions slow down or decline over the past two calendar years for which there is data. Federal funding allocated through the existing Diesel Emissions Reduction Act must continue, allowing states to rebuild diesel-powered vehicle engines to more stringent emission standards or install emission reduction systems, notify affected parties, and share technological information with counties that have poor air quality standards.

Finally, any federal investment must include a focus on resiliency. State and local freight planning should consider adaptation to extreme weather, reduction of local air pollution, water runoff, and wildlife habitat. The United States should also implement competitive grant programs through formula funding that would enable states to assess resiliency vulnerabilities, including sea-level rise, wildfires, landslides, extreme weather and changing temperatures, and dam and levee failures. States should be permitted to use these competitive grant funds for natural infrastructure or aquatic ecosystem restoration elements that are functionally connected to a transportation improvement, with a focus on evacuation routes and critical infrastructure and set-asides for rural communities and Tribal entities.

The transport of goods can be less carbon intensive

The U.S. economy depends on the fast and efficient shipping of goods. The offshoring of U.S. manufacturing jobs to countries with weaker environmental and labor standards, as well as the supply chain disruptions that resulted from the COVID-19 crisis, have shown us the fragilities in this global system. Less obvious is the significant impact the system has on greenhouse gas emissions: freight is responsible for 13 percent of global greenhouse gas emissions.[271]

The majority of goods transported internationally travel by ship.[272] Per ton of cargo, shipping is far more efficient than air transportation. While shipping emissions are theoretically covered under the Paris Agreement, countries are not accounting for international freight under their Nationally Determined Contributions. Emissions from international freight are primarily regulated by the International Maritime Organization (IMO). In 2018, the IMO reached the first agreement to shrink the climate impact from shipping: a 50 percent reduction in emissions by 2050.

Freight trucks are responsible for the majority of goods movement within the United States. Even though they comprise a small percentage of the on-road vehicle fleet, these trucks consume more fuel and generate a disproportionate share of vehicle emissions. The majority of U.S. emissions from freight come from medium- and heavy-duty trucks, together accounting for 23 percent of emissions within the transportation sector. By comparison, ships and boats account for 3 percent of the total, while rail accounts for 2 percent. Long-haul freight activity is expected to increase 40 percent by 2040, and air and marine transportation are also expected to grow.[273]

Greenhouse gas emissions from heavy-duty freight transport can be reduced by improving vehicle efficiency, shifting from trucks to rail, and optimizing supply chains to reduce emissions. Reducing carbon emissions in the heavy-duty fleet involves some obstacles not present in the light-duty fleet, but we can overcome them. Innovation in freight is vital to the future of efficient logistics, a goal major shipping companies in the United States and abroad are increasingly pursuing.

> "If we want to reach our climate goals by 2040, the world has to sell about a billion electric vehicles. […] And if we look at what are the barriers, it's not really a technology barrier, the technologies are known; it's not really a cost barrier…It's a policy barrier. We have to put the right policies in place to put those market signals out there, to get the manufacturers to produce those vehicles, and to get uptake of those vehicles."[302]
>
> **— Rachel Muncrief**
> *Deputy director, International Council on Clean Transportation*

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HEAVY-DUTY VEHICLE STANDARDS. For medium- and heavy-duty vehicles, the EPA and NHTSA are responsible for greenhouse gas emission and fuel efficiency regulations, respectively. The existing regulations to reduce emissions and improve fuel efficiency in the heavy-duty fleet were introduced in two phases. In Phase 1, introduced in 2011, EPA and NHTSA set emission and fuel economy standards for medium- and heavy-duty trucks manufactured in model years 2014-2018. Phase 2 regulations were issued in 2016 and set standards through model year 2027. EPA estimates the final standards will lower carbon dioxide emissions by 1.1 billion metric tons and reduce oil consumptions by two billion barrels over the lifetime of the vehicles sold under the program.[274] Further strengthening these standards is essential to continue addressing the pollution burden from medium- and heavy-duty trucks. Standards should include heavy-duty glider vehicles, glider engines, and glider kits, which the Trump administration attempted to exempt from current standards. California recently adopted protective standards to increase the uptake of zero-emission heavy-duty trucks, highlighting the potential for further progress.

SYSTEM EFFICIENCY. Complementary programs that address the entire freight system can further reduce greenhouse gas emissions. Funding from the Diesel Emissions Reduction Act (DERA) is available to help states, Tribes, regional and local entities, ports, and non-profits achieve significant reductions in diesel emissions. The Green Freight Program takes a system-wide approach to reducing emissions from freight. The program works to improve the energy efficiency of freight systems by focusing on the impact of technology on supply chains, integrating regulatory efficiency standards with fiscal policies and market-based approaches.[275] The EPA participates in the Green Freight Program through the Smart Way Transport Partnership. The Smart Way Partnership is a voluntary program in the United States and Canada that covers all domestic truck, rail, intermodal, and barge freight transport. The program helps advance supply chain sustainability by collecting and sharing data about freight transport and fuel use. Participating companies can identify and select more efficient freight carriers, transport modes, equipment, and operational strategies.[276] The 21st Century Truck Partnership, known as the SuperTruck program, is a public-private partnership that aims to foster technological innovations to increase the efficiency of freight transportation. In a 2015 review the National Academies of Sciences found the SuperTruck program was "a great success."[277] Congress should consider scaling and expanding these programs to achieve additional emission reductions.

PORT ELECTRIFICATION. Greening our nation's ports is an important component of achieving emission reductions in the freight sector. Ports—including coastal, Great Lakes, inland, and river ports—are a critical part of the U.S. economy. They rely heavily on diesel-powered vehicles and equipment for both land and water transport and cargo handling. This results in poor air quality for surrounding communities. EPA estimates that 39 million people live in close proximity to U.S. ports, and 40 percent of ports are located in air quality non-attainment or maintenance areas.[278]

An effective way to reduce the emissions and air pollution from ports is to electrify them. Equipment used in all aspects of freight movement at ports can electrified. Technology is available to electrify everything from cargo handling equipment to harbor tugs and ferries. Ocean-going vessels can be plugged into the shoreside electric grid, and diesel locomotives

used for hauling freight can be replaced with electric locomotives. The Port of Long Beach has begun electrifying its operations with the goal of transitioning terminal equipment to zero emissions by 2030, and on-road trucks by 2035.[279]

In addition to reducing emissions, electrification is cost effective for many ports. Despite the long-term benefits, the biggest barrier to port electrification is access to up-front capital. While states can use DERA money for ports, providing direct federal capital and expanding low-cost financing options to ports can save Americans money on top of the climate and environmental benefits of electrification.

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FREIGHT RAIL. According to the International Energy Agency (IEA), aggressively expanding rail, especially electric rail, across the globe could reduce greenhouse emissions significantly. Rail is already the most efficient form of freight in the United States, but it could be greatly improved with electrification. Unlike much of the rest of the world, this country largely lacks an electrified rail system; less than 1 percent of our tracks are electrified. There are several significant barriers to electrification, but again, the biggest is the up-front capital required for electrification. Congress could provide price signals, incentives, or funding to build new infrastructure that ensures the goods of the future can be shipped where needed by rail—and that rail lines are electrified.

Building a cleaner and more resilient aviation sector

Directly and indirectly, the aviation industry is responsible for 10 million U.S. jobs and $1.7 trillion in economic activity.[280] However, aviation is also a major contributor to the climate crisis, accounting for 2 percent of global emissions. Greenhouse gas emissions from this sector have risen sharply; a report from the International Council on Clean Transportation found that aviation emissions have increased by 32 percent over the last five years.[281] Before the COVID-19 pandemic, emissions from commercial aviation were continuing to rise steeply, on pace to triple by 2050.[282] Standards and regulations for international civil aviation are set by the International Civil Aviation Organization (ICAO), a United Nations specialized agency. Currently, domestic aircraft emissions account for 10 percent of emissions from the U.S. transportation sector.[283]

AIR EMISSIONS STANDARDS. The Clean Air Act provides EPA with the authority to regulate aviation emissions. In July 2020, the agency proposed regulating emissions from aviation for the first time. EPA must use its existing authority under the Clean Air Act to promulgate greenhouse gas emissions from both new and in-service aircraft that are consistent with the need to achieve net-zero emissions globally by 2050.

ADVANCED LIQUID FUELS. One of the biggest challenges to reducing emissions from aviation is the continued reliance, at least for commercial aviation and freight, on liquid fuels. The weight-to-energy ratio of batteries will need to come down significantly before electric aviation becomes a viable alternative for commercial flights. However, some smaller airlines are investing in electric air fleets for shorter trips, including Cape Air in Massachusetts.[284] Since the aviation sector will likely depend on liquid fuels in the near term, we must develop the next generation of cleaner fuels as quickly as possible. Advances are already being made in advanced and cellulosic biofuels. There have also been proposals to create a federal LCFS similar to the one in California for aviation fuels, to bring low-carbon fuels to market. Another potential opportunity is to make synthetic jet fuel from carbon removed from the air through direct air capture.

> "A comprehensive climate plan for U.S. aviation would start with setting both near-term and long-term compliance caps for aeroplane operators."[300]
>
> **— Brad Schallert**
> *Director of carbon market governance and aviation, World Wildlife Fund*

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Investments in research, development, and deployment of new technologies will help bring technologies to market and achieve economies of scale. In 2012, President Obama created the Navy Biofuel Initiative under the Defense Production Act (DPA) to speed the development of "drop in" biofuel substitutes for diesel and jet fuel."[285] This initiative used Title III of the DPA to procure $510 million of biofuels for the Navy. As a result, in 2016 the Navy launched its "Great Green Fleet" using a biodiesel petroleum blend, utilizing biofuels it bought for less than the cost of gasoline.[286] Additional federal R&D spending could aid the development of usable batteries and advanced fuels for aviation.

NON-CO_2 WARMING POLLUTANTS. Most calculations of emissions from the aviation sector do not take into consideration the impacts of non-CO_2 warming pollutants like water vapor, aerosols, and nitrogen. Though we know less about these pollutants, some studies indicate they could be even more damaging than the carbon dioxide emissions from industry because the emissions are taking place at high altitudes.[287] The federal government should fund research into these pollutants so we understand their impacts.

DEVELOPING HIGH-SPEED RAIL. Flying is one of the most carbon-intensive forms of travel.[288] In much of the world, high-speed rail is the quickest, cheapest, and most convenient transportation option for trips under 500 miles. But unlike much of Europe and Asia, most of the United States still lacks a high-speed electric rail system for passengers or freight. Even our conventional rail infrastructure is inadequate to make rail an attractive alternative for most trips. An investment in new rail infrastructure would help the United States catch up with Europe and Asia in providing high-speed rail as a viable alternative to flying.

FINANCIAL AND ECONOMIC RISKS

> Climate-related financial risks are systemic, and if left unchecked, could destabilize our financial markets and economy. Our financial regulators' job is to ensure a stable and efficient financial system, which means they need to start assessing and managing climate risks.

Climate change poses significant risks to the financial system and our nation's economy. The financial industry and the regulators responsible for overseeing it must start taking these risks seriously to avoid a future financial shock. U.S. regulators do not currently require financial institutions to include climate change in their risk management practices. They have dismissed climate risks as too far in the future, too uncertain, and too hard to model. As a result, they are allowing financial companies to increase systemic risk by imprudently financing the activities that accelerate climate change.

Climate-induced disasters already cost banks, insurers, and investors billions of dollars, and those direct losses will increase dramatically over time. Markets will become more volatile, and they may suddenly revalue assets or entire industries to reflect future losses—or even uncertainty about future losses. As BlackRock CEO Larry Fink said in his 2020 annual letter to company chief executives, capital markets "pull future risk forward," and as a result, "we will see changes in capital allocation more quickly than we see changes to the climate itself. In the near future—and sooner than most anticipate—there will be a significant reallocation of capital."[303]

The structure of the financial system increases the odds of a climate-driven crisis. Losses can spread quickly across complex and interconnected firms, and the threat of just one or two companies failing can undermine public confidence in the system as a whole. Furthermore, because there is a near certainty of government intervention to backstop major aspects of the financial system during stress, firms have an incentive to take on more risk.

In the absence of regulatory efforts to curb climate risks, much like in the 2008 crisis, financial companies are profiting now and assuming they can socialize the losses later. Most companies still analyze climate change as a reputational risk, acting in response to public opinion. They

rely on “corporate social responsibility” or niche environment, social, and governance (ESG) product offerings to show action on climate change. While they take steps to phase out financing of the most unpopular and financially risky activities (e.g., thermal coal and Arctic drilling), they continue to underwrite, advise, invest in, and lend to companies at every stage of the fossil fuel value chain without proper consideration of the manifest risks. ESG is an important first step, but it will mean little if it primarily serves a public relations purpose, while financial firms continue facilitating destructive activities without bearing the costs.

Banks, insurers, and investors stand to gain from accurately pricing climate risks and limiting their exposure. A well-regulated financial system makes money when it manages risks well and promotes a strong economy over the long term. The industry may need better data and tools to understand climate impacts—but once financial firms start treating this issue as material to their core business, climate risk management will move out of the corporate sustainability division and into the boardroom. When financial companies apply this shift in risk management to their business activities, clean investments will justifiably look more attractive than continuing to finance the activities that drive climate change.

Financial regulators will be key in getting market participants to start this process, but they themselves are unprepared. Our regulatory agencies must take concrete steps to incorporate climate risk into their financial stability and supervisory responsibilities, including the following:

- The Federal Reserve and other U.S. regulators should immediately join their international counterparts, who are already engaged in an effort to understand climate financial risks.
- The Securities and Exchange Commission (SEC) should issue updated rules on how public companies must disclose climate risks and take enforcement actions against companies that fail to do so.
- The Federal Reserve and other agencies should take the lead in developing climate scenario analysis tools and conduct stress tests on individual financial firms to measure their resilience to climate risks.
- The Financial Stability Oversight Council (FSOC) should assess risks to the financial system as a whole.
- The SEC should require rating agencies to incorporate climate financial risk into their core rating methodologies.
- The Office of the Comptroller of the Currency (OCC), the Federal Deposit Insurance Corporation (FDIC), and the National Credit Union Administration (NCUA) should improve their supervisory practices to incorporate climate risks.
- The Federal Insurance Office (FIO) should assess the insurance industry’s vulnerability to climate risks and make recommendations to state commissioners.
- All federal financial regulators should include explicit discussion of climate risks in their annual reports and other relevant publications.

The consequences of inaction will not be confined to Wall Street. Ignoring climate risks will expose our nation to another financial crisis and economic downturn that will destroy wealth for everyone and overburden the communities who can least afford it. The value of working people's pensions and retirement investments may decline sharply. After the last financial crisis and resulting recession, median household wealth dropped 39 percent between 2007 and 2010.[304] Families throughout the country and across demographics experienced devastating losses, but the households that experienced disproportionate wealth loss were younger, less educated, and Black or Hispanic.[305]

If the financial system prepares now, it can avoid a potential climate-driven financial crisis and the devastating impacts on people across the country that would likely result. The financial industry can also be a key player in ensuring an orderly reallocation of resources as we transition to a cleaner economy. This transition will require investment, and lots of it, which will in turn spur job creation, returns for investors, and significant opportunities in the clean economy.

RISKS OF INACTION

The economic damages of climate change will reverberate through the financial system

Hurting the economy via severe weather events, extreme heat, and sea-level rise

Physical damages from climate-driven events are already causing billions of dollars of damage annually to homes, commercial properties, and infrastructure. 2019 was the fifth consecutive year in which the United States experienced 10 or more weather events with losses exceeding $1 billion.[306] Experts across government,[307] industry,[308] and academia[309] agree that human-caused climate change is a key driver of this trend.

These events have direct economic consequences. People lose their jobs; their homes are damaged or destroyed and become harder to sell. Businesses make less money because workers face extreme heat and natural disasters. They have to divert investments from more productive uses to rebuild and replace assets damaged by climate change.[310] Certain industries are particularly vulnerable. For example, farms and fisheries become less productive, which threatens the livelihoods of workers and undermines our nation's food supply.

Climate-driven damages can severely reduce the value of property and other assets owned by American households, businesses, and state and local governments. In turn, those damages reduce expected returns for lenders and investors who financed those assets. These risks to property and infrastructure are referred to as the ***physical risks*** of climate change. Physical risks will increase in a nonlinear fashion and could reach a tipping point, beyond which they become significantly worse and potentially irreversible.

Causing losses at financial companies

The financial companies that facilitate economic transactions, invest in companies, and lend to businesses and people are experiencing direct losses from climate change now. For instance, investors faced heavy losses[311] when Pacific Gas and Electric (PG&E) filed for bankruptcy in January 2019 because of potential wildfire liabilities that exceeded $30 billion,[312] in what has been called the first climate change bankruptcy.[313] California's homeowner insurers lost $20 billion in the 2017 and 2018 wildfires—twice the industry's cumulative profits since 1991.[314] In East Coast states prone to tidal flooding, coastal property values have declined by $15.8 billion since 2005.[315] The 2016 California drought cost $600 million and nearly 5,000 jobs;[316] a stress test of water risks in nine global banks' loan portfolios found extreme droughts could increase loan defaults tenfold for the most exposed portfolios.[317]

Because of climate change, risks that were once rare are now increasingly common and correlated. Historical datasets are no longer accurate predictors of future losses. To reflect this uncertainty and cover higher losses, insurance, a crucial "shock absorber" after disasters,[318] will become more expensive and less available. This will force households, businesses, and communities to bear the full cost of physical climate damages. For example, after the 2018 fire

season, an estimated 350,000 California residents were unable to obtain property and casualty insurance to cover fire risk; for those with coverage, premiums increased by 300 to 500 percent.[319]

If insurance is no longer available, home sales will likely grind to a halt. Real estate values will then collapse in areas particularly vulnerable to climate change, such as flood-, hurricane-, and fire-prone communities. Dave Burt, an investor who accurately forecasted the 2008 mortgage crisis, testified to the Special Committee:

> In 2007, investors made the irrational assumption that real estate demand would keep increasing indefinitely as more mortgages were given to less and less qualified borrowers. [...] Today, investors are making an equally irrational assumption that the cost of ownership will stay constant even as catastrophe costs increase. This is flawed reasoning and ultimately insurance premiums, taxes, and uninsured losses will increase in risky regions. [...] I wouldn't be surprised if ten years from now, history will wonder how we could have allowed such a bubble to form in the face of such obvious and devastating change.[320]

Like insurance companies, commercial and investment banks face the risk of losses from climate events. For example, climate change increases banks' credit risk (the risk that a borrower cannot repay a loan, or that the underlying asset will not hold its value). Borrowers will be less likely to repay if they lose insurance coverage and their property is damaged or destroyed, or if their income decreases because of climate impacts. Climate change will also drive down the value of properties held as collateral by banks when those assets are damaged, destroyed, or repriced to reflect increased risk.[321] Banks therefore face both a higher probability of borrowers defaulting on loans and higher losses in the event of default.[322] Financial companies will also see increased market risk (the risk that equities, bonds, and other securities lose value) as climate impacts batter entire industries and the economy as a whole.

Smaller banks or credit unions with more concentrated local footprints could face existential threats from physical risks.[323] Climate impacts could affect their entire customer base—for instance, if property values decline in specific geographies hit by floods and wildfires, or many farmers in a single community default on loans during extended droughts or floods. A wave of distress among smaller institutions due to physical risks could be a systemic event in itself, because small banks tend to collapse en masse—a trend we have seen in every banking crisis in U.S. history.[324] Meanwhile, the largest banks have global footprints and multiple revenue streams, so it is difficult to assess their full exposure to climate financial risks. They are only now beginning the process of trying to quantify and model these risks.[325]

Banks, insurers, and other financial institutions should not assume, as they did in the 2008 crisis, that they are insulated from the reckless decisions of their peers, or diversified and nimble enough to avoid destabilizing losses from physical climate damages. They must quickly ramp up efforts to assess and mitigate their vulnerability to these risks. However, the costs of such an accounting must not be borne by the existing homeowners, renters, and business owners in vulnerable communities. Rather, the federal government should incentivize equitable adaptation measures at the local level and facilitate voluntary buyouts for homeowners interested in leaving areas facing sustained climate risks—taking into consideration the needs and input of local communities, especially underserved populations.[326]

The financial system could trigger a climate-related crisis at any time

The complexity and interconnectedness of the financial system increases the risk of a systemic crisis

Too often, market participants are complacent about risk. Post-financial crisis reforms have made some aspects of the industry stronger, but the financial system remains a source of shock and stress, as well as an amplifier and transmitter of disruption throughout the economy.[327]

The U.S. financial system is currently 20 percent of the economy, double what it was in the 1950s.[328] It is comprised of large, complex, and global companies that engage in a broad range of activities. Nine federal regulatory agencies are responsible for overseeing our financial system, but there are major firms that fall outside the federal regulatory perimeter. Among regulated companies like banks, their size and complexity make them difficult to manage effectively—in fact, nearly half of the largest financial holding companies regularly fail to meet supervisory standards.[329] The interconnectedness of financial firms, both domestically and internationally, means stress can spread quickly throughout the system.[330]

The COVID-19 pandemic serves as a reminder of just how vulnerable the financial system is to shocks and how quickly it transmits volatility and heightens uncertainty. The Federal Reserve took extraordinary measures to stabilize markets, including intervening in markets for Treasury securities, mortgage- and asset-backed securities, commercial paper, and money market mutual funds. According to the Federal Reserve, the financial system "amplified the shock" of COVID-19, and without these interventions, sources of short-term funding would have dried up—with dire consequences for the broader economy.[331] In the 90 days between February 27 and May 28, 2020, the Federal Reserve provided financial markets with nearly $3 trillion to prevent a financial and economic collapse.[332]

Climate change remains the biggest threat on the horizon, and the current fragility of the financial system increases the likelihood that climate risks will spark a systemic crisis.

Waking up the market

There are several scenarios in which climate risks might drive financial markets into a sudden correction. The realization of accelerating physical risks themselves could trigger a market correction. Alternatively, the market could price in the risk of volatility related to a "disorderly" transition. In other words, a delayed policy response to the climate crisis would necessitate more forceful and abrupt climate regulations in the future, which could panic markets and cause unpredictable swings in asset prices. Because Congress has not advanced any comprehensive climate policies in the last decade, the market has not priced in the possibility of significant federal action.[333] But around the world, climate mitigation policies are becoming more common.

With or without the United States' leadership or cooperation, other countries will move ahead with actions necessary to achieve their commitments under the Paris Agreement. This might come as soon as 2023-2025, when signatories will conduct the first global account of progress towards the Agreement's goals and commit to a new round of pledges.[334] As countries pursue ambitious mitigation efforts, they

may impose protectionary trade measures to help their industries compete with those in countries with lax emissions policies. Already the European Union has proposed "carbon tariffs" on countries that do not abide by Paris commitments.[335] Because of the global nature of their operations, multinational corporations are exposed to policy impacts regardless of where they are headquartered.[336]

The switch to a clean economy will also be driven by shifting consumer preferences.[337] The sustainable and responsible investing industry has enjoyed 18-fold growth since 1995.[338] Investment firms are increasingly offering ESG products because there is enormous demand for responsible investment options—asset managers have to keep up with this demand or risk losing a share of the growing market. The shift in public opinion is moving faster than the pace of policymaking, which may accelerate action on climate mitigation in both the private sector and government.

Ensuring our survival involves some measure of disruption

The scientific imperative for climate action is well established and urgent. The longer we delay, the more unmanageable climate impacts will become. The only way to avert these physical risks is to mitigate climate change. Namely, it requires recognizing the risks of carbon pollution and shifting towards a low-carbon economy. This process—or more accurately, the mere realization that this process is imminent—will drive down the value of assets tied to the carbon-sensitive energy, electric power, and transportation sectors, among others. The risk of holding this type of asset, which will lose value in a low-carbon economy, is referred to as ***transition risk***.[339]

Companies involved in fossil fuel production or downstream products, such as fossil-dependent utilities or manufacturers of internal combustion engines, will see demand for their products decrease—potentially rapidly and unexpectedly.[340] For the financial system, the disruptive moment will not be when the climate transition itself is fully underway; it will be when the market begins to account for the inevitability of that transition.

When the transition to a clean economy appears inevitable, some portion of existing fossil fuel reserves will become noncompetitive. Already, fossil fuel assets in the power sector are losing ground to lower-cost renewable options.[341] Unburnable fossil fuel reserves will become "stranded assets." Every stranded asset represents the cost of the initial capital expenditure, as well as the lost revenues that the company and its investors expected the asset to generate. These losses could be significant: some estimate the value of potential stranded assets could reach $18 trillion.[342] The stranded asset problem will not be limited to the energy sector—other impacted industries could include utilities, automobiles, aviation, shipping, real estate, and heavy industry.[343]

A sudden and significant decrease in the value of fossil fuel-related assets presents a significant risk to asset managers of mutual funds, pension funds, and insurance firms (which are major institutional investors because they invest policyholder premiums and use their returns to pay out claims). Financial firms that manage money on behalf of beneficiaries and investors have some discretion over how to invest the money they are entrusted with. However, they have an obligation to act in their clients' best interests.[344] This includes matching investment strategies with clients' risk tolerance and objectives. In the case of pension funds, for example, investments must have long time horizons: generations of pension beneficiaries depend on prudent stewardship of their retirement savings. It should be clear that fiduciaries are obligated to consider risks and trends that may materialize over

decades. Ignoring the risks related to the stranded asset problem therefore constitutes a failure of fiduciary duty.[345]

The companies whose assets become stranded may experience severe credit downgrades, and their outstanding equity and debt securities will lose value. It would only take a fire sale—the sale of assets at heavily discounted prices by a distressed seller—at one bank to disrupt trading at its counterparties with similar holdings. This is how large financial firms transmit price shocks through the financial system.

The risk is not that *every* loan goes bad, or that *every* mispriced carbon-intensive company goes bankrupt. Rather, it is that a fire sale of securities tied to stranded assets could cause a broader price shock, and general uncertainty around the valuation of all assets linked to future carbon emissions. And as companies find themselves unable to repay creditors and derivatives counterparties, losses would cascade throughout the financial system.[346] This is what former Bank of England Governor Mark Carney characterized as a "climate Minsky moment"—a bursting of the carbon asset bubble.[347]

> "In risk management, time is a scarce resource. It's when one runs out of time that a risk can turn into a disaster… With climate change we do not know how much time we have before the planet's climatic system is pushed past a catastrophic tipping point, beyond which the consequences would become non-linear and irreversible."[397]
>
> **— Bob Litterman**
>
> *Founding partner and Risk Committee chairman, Kepos Capital; chair of the Climate-related Market Risk Subcommittee, Commodity Futures Trading Commission*

Controlling how orderly the transition will be

An early and orderly reallocation of capital can prevent necessary climate mitigation strategies from triggering a financial crisis. As a starting point, financial firms must begin to understand their exposure to climate risks and reorient away from risky assets and activities. However, as Frank Elderson—the executive director of the Dutch central bank, De Nederlandsche Bank—told the Special Committee, an orderly transition is only possible through stable and predictable policies.[348] Timely, unambiguous climate legislation and regulations will give markets the direction they need to reallocate capital in a controlled manner. This will still involve some measure of economic turbulence, including asset repricing, but the magnitude of disruption is dependent on how soon and how forcefully we act. If the moment comes in the near future, markets will have ample time to adjust to a new, low-carbon economic outlook, and direct capital accordingly. But the longer we put off the transition, the faster we will eventually need to decarbonize our economy. That faster transition will increase the risk that multiple financial firms act suddenly and simultaneously to reduce their exposure to carbon assets.

Sarah Bloom Raskin, a former member of the Federal Reserve Board of Governors and Deputy Treasury Secretary, testified to the Special Committee about the risk of a disorderly transition: "The point is that a dramatic, sudden and lagged reassessment and readjustment of financial assets" would risk "destabilizing markets, sparking potentially pro-cyclical catastrophic losses and leading to a persistent tightening of financial conditions. These are hallmarks of financial instability." Raskin added, "Many analysts now believe that a sudden transition could be sufficiently disruptive to trigger a recession."[349]

PROGRESS AND OPPORTUNITIES

Financial regulators have the authority and responsibility to mitigate climate financial risk

Promoting financial stability and rooting out systemic risks

The purpose of financial regulation is to ensure the soundness and stability of the economy. After the 2008 crisis, our financial laws strengthened regulators' authorities to head off future financial crises and lessen the damage from exogenous shocks to the financial system. Smart financial regulation forces firms to internalize the costs of the risks they take, and discourages activities that threaten the stability of the entire system.

U.S. financial regulators are not doing their jobs when it comes to climate risk. They are ignoring the near certainty that climate change will upend the stability of the financial system, the health of the economy, and even the habitability of whole regions of the world. Ignoring climate risk is not a neutral position. In failing to discourage financial firms from financing activities that amplify the climate crisis, U.S. regulators allow firms to take risks that will ultimately be borne by other economic participants and taxpayers.

Our regulators should use their tools—like prudential regulation and supervision—to discourage imprudent investments in climate change-accelerating activities that present significant risks to financial institutions, and require firms to improve their resilience to climate risks. For example, regulators could adjust the risk weighting of climate change-accelerating activities and require disclosures of firms' financing of such activities. They could conduct climate stress tests to make sure financial institutions are resilient against both physical and transition risks. They could clarify rules to make clear that prudent and loyal consideration of climate risks in investment decisions does not violate fiduciary duty. In fact, regulators could articulate that fiduciary duty *requires* asset managers to assess which activities destabilize the economy. And they could require publicly traded companies to disclose to investors their emissions and vulnerabilities to climate change.

Climate change is not just another exogenous shock—it is the result of financial market preferences that run counter to the long-term public good.[350] There are lucrative fees and short-term returns to be made financing and investing in the activities that accelerate climate change. Financial firms currently believe they can somehow avoid the costs later, because those costs are largely in the future, spread out, and likely to fall on taxpayers. Financial regulators have the authority and the responsibility to curb this reckless behavior.

Enforcing better disclosure of climate risks

Investors, rating agencies, insurers, and the general public need to know exactly how exposed individual companies are to climate risks, and how they intend to manage those risks. Unless that information is publicly available, detailed, and easily comparable across different companies, market participants will not know how to prepare for climate change. Namely, they will not know how climate risks affect firms' business activities, supply chains, assets, and financial planning.

The Securities and Exchange Commission (SEC) issued guidance in 2010 on how companies should disclose climate risk, but the vast majority of investors feel the Commission has failed to adequately enforce that guidance.[351] In October 2018, a group of investors representing $5 trillion in assets, along with several leading securities law professors, sent a petition to the SEC arguing that improved ESG disclosure rules would increase market efficiency and that the SEC has the authority to issues such rules.[352]

Sarah Bloom Raskin emphasized the importance of disclosure in her testimony to the Special Committee:

> Without regular, timely climate disclosures, a sudden and unexpected substantial devaluation of carbon-dependent assets could trigger another financial crisis. But with regular climate disclosures, companies would publish information on their exposure to climate-related risks and their actual and planned responses to new regulations and changes in consumer demand. This information should ensure financial stability.[353]

The Financial Stability Board's industry-led Task Force on Climate-related Financial Disclosures (TCFD) has published recommendations for how companies should voluntarily disclose climate risks. The recommendations span governance, strategy, risk management, and metrics and targets. While some companies are working to implement the recommendations,[354] the TCFD is "concerned that not enough companies are disclosing *decision-useful* climate-related financial information."[355]

Investors echo this sentiment. In a July 2020 survey of 14 institutional investors, the Government Accountability Office (GAO) found that 12 of the 14 look at ESG disclosures "to better understand risks that could affect company financial performance over time." The investors use those disclosures to inform their voting at shareholder meetings and make stock purchasing decisions.[356] However, "most institutional investors said that there is fragmentation in the format or location of companies' ESG disclosures, which can make this information hard to compile and review."[357]

The status quo of voluntary, piecemeal climate risk disclosure needs to improve—another survey found that more than 90 percent of investors disagree that voluntary reporting adequately meets

investor demand for ESG information.[358] Instead, the SEC should issue updated rules demanding companies disclose climate risks, and take enforcement actions against companies that fail to do so. Specifically, it should require every public company to disclose its greenhouse gas emissions, its exposure to physical and transition risks, and its climate risk management strategy.

The SEC also oversees credit rating agencies through its Office of Credit Ratings. These firms, like many others, have not fully accounted for climate risks in their core products—in this case, corporate credit and bond ratings.[359] Their incomplete accounting impacts the entire financial system, since it enables easy credit access for the very companies that are driving the climate crisis. The SEC should therefore require rating agencies to incorporate climate financial risk into their core rating methodologies, rather than relegating it to ESG-focused side products.

Incorporating climate risks into the Federal Reserve's supervisory and monetary policy frameworks

Managing climate risks is a natural extension of the Fed's core responsibility to ensure a stable and efficient financial system. Lael Brainard, a member of the Federal Reserve Board of Governors, acknowledged in 2019: "[c]limate risks are projected to have profound effects on the U.S. economy and financial system," and to fulfill the Fed's "core responsibilities," it will be important for the Fed to "adapt [its] work accordingly."[360] Dr. Sabine Mauderer, a member of the executive board of Germany's central bank, the Deutsche Bundesbank, testified to the Special Committee that central banks and financial regulators have "a clear mandate to take into account a potentially systemic impact of climate-related risks on the financial system," which will require developing "analytical frameworks with longer horizons."[361]

Dozens of central banks and bank supervisors from around the world—organized as the Network for Greening the Financial System (NGFS)—are already working together to develop "new analytical and supervisory approaches, including those based on forward-looking scenario analysis and stress tests."[362] The Fed should conduct stress tests on individual financial firms to measure their resilience to climate risks and work with the Financial Stability Oversight Council (FSOC) to assess risks to the financial system as a whole. There is precedent for both of these approaches among the Fed's peers, for example, De Nederlandsche Bank's stress test of transition risks to the Netherlands' financial system,[363] and the Bank of England's planned exploratory stress test of individual firms.[364]

In addition to incorporating climate risks into prudential regulation and financial stability surveillance, the Fed must account for these risks in monetary policy: its work to buffer the economy from unexpected shocks and achieve maximum employment and price

stability.[365] Governor Brainard argued, "it is vital for monetary policymakers to understand the nature of climate disturbances to the economy, as well as their likely persistence and breadth, in order to respond effectively."[366] The Fed's counterparts around the world agree that climate risks will "have persistent impacts on macroeconomic and financial variables … that are fundamental to achieving central banks' monetary policy mandates."[367] For that reason, "the NGFS will consider exploring … the effects of climate-related risks on the monetary policy frameworks."[368]

The Fed appears be evolving on the issue of climate risks. At a January 2020 press conference, when asked if climate change posed a risk to financial stability, Federal Reserve Chair Jerome H. Powell answered: "I think the public has every right to expect and will expect that we will assure that the financial system is resilient and robust against the risks from climate change."[369] Powell went further in a February 2020 response to a letter from senators: "Our goal is to marshal our expertise, in order to further the supervisory community's assessment and measurement of these risks, and to ensure appropriate supervisory expectations around financial institutions' management of climate-related financial risks."[370]

The risk now is that the Fed moves too slowly to turn these promising statements into concrete actions. Vice Chair Randal K. Quarles told the Senate Banking Committee in December 2019 that the Fed is "exploring" joining the NGFS, and is "closely engaged" with the Bank of England on "how they are looking at climate change in regulation and supervision."[371] The Fed should take the logical next steps of joining the rest of the world in the NGFS; requiring firms to incorporate climate change into their core risk management; conducting climate stress tests; and analyzing how climate risks will affect its financial stability and monetary policy goals.

CASE STUDY: THE BANK OF ENGLAND'S CLIMATE STRESS TESTS

In 2018, the Bank of England announced its intention to include climate change in its bank stress tests as part of its biennial exploratory scenario. The exploratory scenario is "the part of the Bank's stress testing framework used to explore less well-understood risks that are not neatly linked to the financial cycle."[398] The announcement followed a survey that showed only 10 percent of banks were taking a long-term view of climate risks.[399]

The Bank of England will test climate risks under three scenarios.[400] The first envisions an orderly transition, in which immediate policy action enables net-zero emissions by 2050, limiting warming below 2 degrees. The second involves a delayed policy response, leading to a sudden and disruptive transition. The third imagines that no additional policy action is taken: the world continues on its current emissions path, and warming exceeds 3 degrees—what the NGFS calls a "hot house world" of unchecked physical risks.[401] Each of these scenarios implies a trade-off between physical and transition risks that will affect financial firms in unique ways.

The Bank of England's test will be a "two-part exercise:" first, participating banks will quantify the change in the value of their assets at five-year intervals in each scenario, and second, participants will assess how they would change their business models in response to each scenario. For example, a bank might reduce its exposure to at-risk sectors while reorienting its business to take advantage of new opportunities. The Bank of England will then assess the plausibility of the banks' planned actions in aggregate.[402]

The Bank of England recognizes that climate impacts and mitigation policies will occur over a much longer timeframe than the standard stress test horizon. Specifically, the Bank plans to use a 30-year modeling horizon for its climate stress tests. This is an attribute the Federal Reserve has cited to explain its own inaction. In May 2020, Fed Chair Powell said that because climate stress testing involves scenarios that "stretch well beyond the current stress tests," the "uncertainty of such long-horizon economic forecasts would dramatically reduce the plausibility and relevance of the results."[403] However, the Bank of England is not testing the adequacy of banks' capital to absorb climate risks. Instead, it is examining firms' vulnerabilities using their current balance sheets, which will "shed light on the scale of adjustment required by the financial system over the coming years/decades."[404]

In June 2020, the NGFS published a standardized set of climate scenarios, along with a user guide for central banks to integrate the scenarios into stress tests.[405] Since the Bank of England's announcement, regulators in France, Australia, Singapore, and at the European Central Bank have announced their own plans for climate stress tests.[406]

Although the COVID-19 pandemic forced the Bank of England to postpone its bank climate stress test until mid-2021,[407] the Bank also regulates the UK insurance industry, and already included climate scenarios in its 2019 stress test of insurance firms. That test of insurers' liabilities and investments, like the planned bank stress test, aimed to "promote discussion on how business models and balance sheets may need to adapt" in response to climate change.[408]

Other regulators also have the authorities they need to begin mitigating climate risk

The Office of the Comptroller of the Currency (OCC), the Federal Deposit Insurance Corporation (FDIC), and the National Credit Union Administration (NCUA) should also require firms under their jurisdiction to incorporate climate change into their core risk management practices.

While insurance is primarily regulated at the state level, the Federal Insurance Office (FIO) can and should assess the industry's vulnerability to climate risks and make recommendations to state commissioners and FSOC. It should also assess the risk to households, businesses, state and local economies, and the financial system if the insurance industry's response to climate change is to stop offering certain types of coverage, or to withdraw from some markets altogether. Meanwhile, the National Association of Insurance Commissioners (NAIC)—a standard-setting organization comprised of the chief insurance regulators of each state—adopted an "Insurer Climate Risk Disclosure Survey" in 2010. Today, six states administer the survey to companies licensed in their states that write at least $100 million in premiums.[372] The NAIC should encourage more states to administer the survey, and continue its work to align the survey with TCFD-like disclosures that provide more useful and comparable information across insurers. The FIO and NAIC should also work together to establish clear standards for how insurers must begin responding to climate risks while continuing to offer affordable coverage. Finally, state insurance regulators should require insurers to conduct climate stress tests and scenario analyses, a step the Bank of England is already taking for major U.K. insurers.[373]

All federal financial regulators could include explicit discussion of climate risks in their annual reports, supervisor manuals, and other relevant publications. FSOC, in particular, could begin assessing the systemic risks posed by climate change and publish its findings in its annual report, and should consider creating a climate risk subcommittee to carry out this effort.

There has already been laudable progress from a few regulators. The Commodity Futures Trading Commission (CFTC) created a 35-member Climate-related Market Risk Subcommittee in July 2019, with a mission to "identify and examine the risks that climate change poses to the stability of our financial system, and determine what future actions policymakers and market participants must consider to mitigate these risks."[374] Regional Fed banks are also engaged in research on climate risks—the Federal Reserve Bank of San Francisco, for instance, held the Fed's first ever conference on the economic risks of climate change in November 2019.[375]

There are financial opportunities in climate action

Improving economic growth through climate action

The International Energy Agency concluded that the world's clean energy investments are currently only one-third of what will be necessary to have a hope of staying within 2 degrees Celsius of warming.[376] This massive energy spending gap, and gaps in other sectors like transportation and sustainable agriculture, could prove to be some of the greatest financial opportunities—and sources of employment— of the century.[377]

The firms that finance, advise on, and invest in this transition will do so not on ideological grounds, but because they stand poised to capture enormous revenue opportunities. Goldman Sachs, for example, recently pledged $750 billion towards financing the climate transition and sustainable growth because it saw "a powerful business and investing case."[378] The majority of studies found positive correlations between ESG considerations and a company's financial performance, including lower costs of capital, improved operating performance, and stronger free cash flow.[379] BlackRock said in a May 2020 research note that 88 percent of sustainable indexes outperformed non-sustainable counterparts in the turbulent first four months of 2020—just as they did during market declines in 2015-2016 and 2018.[380] Ultimately, responsible businesses "should be better positioned versus their less sustainable peers to weather adverse conditions while still benefiting from positive market environments."[381]

> "This seems like an extraordinary challenge, but it really is not different from what financial firms – banks, insurance companies, pension funds, and asset managers – do to manage other risks they confront in the ordinary course of business. They need to understand what they are holding, and they must be informed about the extent to which their assets are affected by increasing financial risks associated with climate change."[409]
>
> **— Sarah Bloom Raskin**
>
> *Former member of the Federal Reserve Board of Governors and Deputy Treasury Secretary*

Eliminating *de facto* subsidies

When regulators allow banks, insurers, and rating agencies to underprice the financial impacts of climate change, they are not only exposing our financial system to physical and transition risks—they are also encouraging ongoing investment in carbon-intensive industries. Doing so provides those sectors with an implicit subsidy and exacerbates the financing gap between fossil fuels and clean energy.[382]

Artificially cheap equity funding for fossil energy can crowd out financing for clean energy.[383] If banks and investors accurately priced climate risk, clean investments would properly look more attractive than carbon-intensive investments. Similarly, if credit rating agencies properly accounted for climate risks and the opportunities some industries will enjoy in the transition, clean companies could obtain the investment-grade ratings necessary to access long-term bond markets.[384] If enough participants in our financial system start recognizing the reality of climate risks, markets will reorient, affecting every other sector of the economy.

Unlocking productive investments

The cost of climate-driven catastrophes is increasing. Adjusted for inflation, the U.S. experienced more than twice the number of billion-dollar disasters in the 2010s than the 2000s.[385] The five years from 2015 through 2019 were the most expesive stretch on record.[386] Furthermore, when government agencies and insurance companies quote the dollar value of damages from a disaster, they are generally quoting an estimate of what it will cost to rebuild the property damaged or destroyed. But this is not an accurate measure of a disaster's true economic cost. An accurate measurement would also consider the productive investments that were "crowded out" by the costs of rebuilding.[387]

Every dollar put towards rebuilding is a dollar unavailable for forward-looking investment.[388] As we need more investment over time to drive our economic transition, we cannot afford to divert capital to the constant cycle of rebuilding after climate-related disasters. At a minimum, we must break the norm of rebuilding to pre-disaster standards and leaving infrastructure equally vulnerable to future climate events. We can no longer hope to entirely avoid the costs of climate disasters. However, if we rebuild in a more resilient and sustainable manner and take aggressive steps to reduce emissions, we can free up money to invest in innovative—and profitable—solutions to the crisis.

Neither the U.S. financial sector nor its regulators have to figure this out on their own

Leading the development of scenario analysis tools

The work of assessing climate financial risks is a substantial task, and one the industry reasonably hopes federal regulators will approach in a consistent manner across firms and jurisdictions. Our regulators need to lead the way in developing the information and tools necessary to quantify these risks.

The sooner federal financial regulators act on climate risks, the sooner they can begin developing the data necessary for commercially available climate scenario tools. These tools will accelerate the pace at which financial institutions can see how physical impacts translate into economic damage—and then into financial risks at the company, portfolio, asset class, and sector levels.[389] If we want actors at every level of the financial system to begin accounting for climate risks, we should develop the standardized and publicly available tools that will allow them do so.

Following the roadmap that regulators worldwide are providing

In order to develop an understanding of how climate risks will affect financial stability, our regulatory agencies need data, methods of measuring climate impacts, and analytical frameworks with longer time horizons than they are accustomed to.[390] This work is already ongoing, and our regulators will benefit from joining their counterparts around the world.

In October 2019, the Special Committee heard from central bankers from the Netherlands, France, Germany, and Norway about their approaches to climate-related financial risk. Frank Elderson of De Nederlandsche Bank, one of the participants, also serves as chair of the NGFS. He described the network as "a coalition of the willing" whose members are committed to the analytical work necessary "to equip central banks and supervisors with appropriate tools and methodologies to identify, quantify and mitigate climate-related risks in the financial system."[391]

The work of the NGFS is structured along three workstreams: supervision, macro-financial impacts, and the mainstreaming of green finance.[392] In its first comprehensive report,[393] the group issued a set of recommended actions for central banks and supervisors. These include integrating climate risks into financial stability monitoring and micro-supervision; building climate risk assessment into central banks' own-portfolio management; and data sharing and technical assistance to help bridge information gaps.[394] U.S. financial regulators should actively participate in the NGFS's workstreams and implement the group's recommendations without delay.

The NGFS has now begun publishing a series of technical documents to establish specific best practices for achieving those recommended actions. The group published the first of these manuals—a guide to integrating climate risks into prudential supervision—in May 2020. The NGFS will continue to develop the data and methodologies necessary for

supervisors to implement its recommendations, with the goal of "developing an international approach that is as harmonised as possible."[395] Although the NGFS's recommendations are non-binding, central banks are already implementing them. Nathalie Aufauvre of Banque de France told the Special Committee that France's regulators "decided to 'walk the talk' as soon as possible," because they "want to lead by example in order to send the right signals to both our community (of central banks and supervisors) and the financial sector at large."[396]

The point is not merely that U.S. regulators have a responsibility to catch up to their international colleagues on climate-related financial risks. They should *want* to participate in the ongoing effort to design a collective response to those risks. The work of assessing climate financial risks is a complex undertaking with little precedent—but our regulators do not have to figure it out in a vacuum. As is true of any effort to confront the climate crisis, collective leadership and coordinated action will be essential to success. Our financial and economic well-being depend on America joining this global effort.

CLIMATE-SMART COMMUNITIES

> Action on climate resilience and mitigation at the local level provides significant return on investment by increasing livability, stimulating economic activity, and lowering the costs and societal disruption of natural disasters. Done correctly, these investments can also make communities healthier and improve equity for all residents.

Communities around the country are already experiencing the physical and economic impacts of climate change. In response, many local governments across the United States are moving forward with bold climate mitigation and resilience strategies that suit their unique circumstances and their residents' needs. But local decision-makers need support from the federal government to accelerate these efforts. It is at the local level where the nexus of federal action, community planning, and individual decisions can come together to both significantly reduce emissions and ensure we are resilient to increasing climate impacts.

In the last decade, cities and towns throughout the United States have invested substantial time and funding toward addressing climate change. They are becoming incubators of innovation, generating solutions that can be scaled nationwide. Many cities and towns have developed community adaptation plans, set renewable energy targets, embraced green infrastructure solutions, and much more. The data from these cities confirm that local decisions are essential to tackling the climate crisis—and these investments provide good returns. Studies show that $1 spent on improving community resilience is worth upwards of $6 in benefits.[410]

However, climate-smart planning should not be narrowly interpreted as building roads a few inches higher or hardening a coastline. To prepare communities for climate change, we must think more broadly. We must ensure that a community's housing, transportation, and infrastructure work for all residents—making it a better place to live, economically stronger, healthier, and more socially diverse. This approach can also enable us to address the legacy of planning decisions that have resulted in low-income communities and communities of color facing higher risks from extreme events and greater exposure to environmental pollution.

"To effectively address climate change, the national climate policy agenda must drive actions that result in real benefits at the local and community level, including pollution reduction, affordable and quality housing, good jobs, sustainable livelihoods, and community infrastructure."[510]

— Dr. Cecilia Martinez

Co-founder and executive director, Center for Earth, Energy, and Democracy (CEED)

Communities investing in resilience experience fewer losses during a disaster and can resume normal activities faster. Resilient housing allows people to stay in place or return quickly after an extreme event. It means maintaining the fabric of communities and business activity, thereby reducing job losses. Ultimately, resilient neighborhoods and business districts help attract commercial development and a thriving population, strengthening a community's tax base.

Cities and towns can also reduce emissions and improve air quality by putting homes, jobs, stores, parks, schools, and other destinations close to each other. This enables people to walk, bike, or use public transportation more often, thereby driving less. Reducing the distances people travel in a day—specifically in urban and suburban areas—will significantly reduce tailpipe emissions from cars, trucks, and buses that currently account for over one-fifth of the United States' total carbon pollution.[411,412] But these strategies also work for rural towns looking to maintain or revive their "Main Street," and with it, small businesses and a sense of community.

We are already seeing the rising cost of climate impacts, made worse by aging and inadequate infrastructure. The United States has an infrastructure funding gap of about $2 trillion.[413] Estimates show that this lack of investment will result in significant costs, including $3.9 trillion from U.S. GDP and $7 trillion in lost business sales by 2025.[414] This gap provides us with an opportunity to direct significant new funding towards neglected projects—but with designs that increase resilience and provide numerous co-benefits. Doing so will also create thousands of construction jobs throughout these communities.

The shift towards resilience planning and smart growth at the local level must accelerate just as rapidly as the climate is changing. And we will need to mobilize considerable funds to ensure that all community planning activities are focused on increasing resilience and reducing emissions.

Congress can help support communities in several ways:

- Providing new funding and financing mechanisms for local projects that promote green infrastructure, microgrids, smart growth, and smart and efficient buildings.
- Incorporating resilience priorities into existing federal projects and programs and improving coordination among them.
- Providing federal incentives for cities and towns that adopt progressive building and zoning codes, retrofit old buildings, and de-risk communities.
- Empowering local leaders with climate data and planning tools to build a new pipeline of innovative resilience projects.
- Providing federal support to enable low-income communities and families to invest in their own resilience.
- Disincentivizing new development in current and future flood-prone areas and equitably addressing existing at-risk properties.

Communities are already struggling with the impacts of climate-fueled disasters and require the immediate attention and support of the federal government. Dollars spent on resilience efforts now will determine the quality of life and safety of Americans for decades to come.

RISKS OF INACTION

Extreme weather events are already impacting communities

Flooding is the most common—and most costly—natural threat to our nation's communities.[415] From 2000 to 2018, hurricanes in the United States caused more than 6,000 deaths and $800 billion in economic losses, largely due to flooding and storm surge.[416] Looking forward, 386,000 existing U.S. homes, worth about $210 billion at today's prices, are likely to be at risk of regular annual flooding by 2050 because of sea-level rise from climate change, including many in low-income communities.[417] In addition to increasingly frequent and severe weather events, hundreds of coastal communities now face chronic inundation from disruptive sunny-day flooding as sea levels rise.[418] This nuisance flooding—so named because it causes public inconveniences like frequent road closures, overwhelmed storm drains, and compromised infrastructure—has increased on the East, Gulf, and West coasts between 300 and 925 percent since the 1960s.[419] Climate change is also affecting shoreline erosion in the Great Lakes, threatening homes, business, and tourism dollars.[420]

Inland and riverine flooding is also a growing threat, particularly to rural communities. The 2014 National Climate Assessment found that riverine flooding from excessive inland precipitation is on the rise in many U.S. regions, disrupting public utilities, road and rail transportation, and inland navigation, and causing billions of dollars in damage and lost agricultural revenues annually.[421] 2019 was the second wettest year ever in U.S. history, causing $6.2 billion of damage in the Midwest alone.[422]

Extreme heat in the United States already causes more deaths than any other type of severe weather, killing hundreds of Americans each year.[423] Prolonged periods of high heat will exacerbate the urban heat island effect: the tendency for cities to have higher surface temperatures because asphalt, pavement, and cement absorb and emit heat.[424] The annual mean air temperature of a city with a population of 1 million or more can be 1-5 degrees Fahrenheit warmer than its surroundings, and up to 22 degrees higher at night.[425] The urban heat island effect tends to be most extreme in areas that lack tree coverage or other vegetation, which strongly correlates with lower-income neighborhoods, putting them at even greater risk.[426] In the coming decades these impacts will increase, and cities will face more extremely hot days.[427] When temperatures reach extreme levels, worker productivity is reduced, roads and railroads can buckle, airports shut down, and lives are at risk. Severe heat is also a growing threat to the health of agriculture workers and reduces farm productivity.

In areas of the Midwest, the heat index is projected to surpass 100 degrees Fahrenheit on an average of 30 days per year by 2036, up from the current average of 6 days per year.[428]

Hotter temperatures and changing precipitation patterns contribute to prolonged droughts and increased risk of catastrophic wildfire. One of the most tragic examples in recent years was in Paradise, California, where 11,000 homes were destroyed and 85 people died in the 2018 Camp Fire.[429] One year after the fire, only 11 of these homes were rebuilt; the community's population decreased from 26,000 to roughly 3,000.[430] A California state official responsible for fire protection suggested that fire season is "not a season anymore – it's year-round."[431] This year-round battle to manage wildfires is becoming a new reality for states across the country. Nearly 30 percent of properties in Montana are at risk from wildfires, as are more than 25 percent of all properties in Idaho.[432] For communities that depend on tourism and recreation, the economic aftermath of wildfires can inflict more harm. After the Hayman Fire destroyed over 100,000 acres of forest outside Colorado Springs, the local economy lost $2.6 million in tax revenue, sales tax, and recreational business revenue.[433]

Climate disasters cause lasting social and economic damage

Recent events prove that communities do not quickly rebound after a natural disaster, and the economic effects can persist for decades. Tragically, about 40 percent of small businesses never reopen after a disaster.[434] A Federal Reserve survey found that small businesses affected by natural disasters have "sizable revenue and employment gaps and elevated incidence of financial challenges compared to unaffected firms."[435] Following Hurricane Katrina in 2005, New Orleans lost 40,000 jobs, and as of 2018, employment in the New Orleans area remained below pre-Katrina levels.[436] Severe disasters in the United States (those leading to 25 or more deaths) have decades-long effects on economic activity at the county level.[437] Furthermore, the notion that disaster recovery stimulates economic growth is misguided. Money diverted to rebuilding after a disaster is simply capital that is unavailable for productive, forward-looking investment. As an economist at the Federal Reserve Bank of St. Louis put it, "money spent to replace a bridge in a city is money that cannot be used to provide that city with new street lighting or to replace a worn-out bridge in another city."[438]

Flooding from Hurricane Katrina

Exacerbating inequalities and threatening health and well-being

As our nation deals with deteriorating infrastructure and widening economic inequality, unchecked physical climate impacts will amplify existing challenges in our most vulnerable communities. For example, communities of color and lower-income Americans are at the greatest risk of injury and illness from extreme heat,[439] and these communities have a lower capacity to prepare for and cope with more intense extreme weather events.[440] In recent disasters, racial minorities have suffered the worst and recovered the slowest.[441]

> "While everyone is being impacted by climate change, the sad reality is that our most vulnerable residents are most susceptible to harm. They will pay the steepest price of any inaction. Those communities are hit first and hit the hardest, and they have less ability to react and recover."[511]
>
> **— Keisha Lance Bottoms**
> *Mayor of Atlanta*

Although large and well-resourced communities have created offices and programs to coordinate climate adaptation efforts, the response has lagged in smaller and lower-income communities.[442] This means climate impacts, like regular flooding, lead to harmful secondary impacts like lost wages and lost school days.[443] Culturally and economically, displacement due to extreme events may forever change the places left behind.[444] County-level poverty rates historically increase by more than one percentage point after large disasters: housing prices decline, wealthier residents move out, and the remaining community tends to transition into poverty.[445]

Climate change inequality extends to rural areas, where the local economy is often highly dependent on a few industries like agriculture, ranching, forestry, recreation, and tourism, all of which are highly susceptible to climate threats.[446] Rural communities tend to start off with lower average income,[447] higher rates of poverty,[448] and lower GDP[449] than urban counterparts, and climate-induced weather events will likely continue to increase this divide. With an unprecedented number of rural counties already experiencing historic population declines, climate change can accelerate outmigration of young adults in communities impacted by extreme events, weighing on rural economies and increasing poverty rates.[450]

High housing costs push poorer people into riskier housing without adequate insurance, where they have limited ability to avoid impacts and lack the financial resources to cover a disruption.[451] This leaves people exposed and reliant on post-disaster recovery programs, which too often take too long to provide relief and do not reach the people who need it most.[452] A lack of financial resources could also mean that buying a hurricane preparedness kit, which can cost hundreds of dollars, is impossible; or that when a storm, flood, or fire comes, families cannot afford to evacuate.[453]

Native communities are also particularly vulnerable to climate-driven disruption. Climate impacts interfere with subsistence and cultural practices, like agriculture, hunting, and fishing.[454] Native communities in different regions of the country are considering or actively pursuing community relocation as a climate adaptation strategy, which is costly and will strain cultural continuity.[455] In January 2020, five Indigenous coastal communities—one in Alaska and four in Louisiana—filed a complaint with the United Nations, asking for an investigation into the U.S. government's negligence in failing to provide resettlement resources to Indigenous communities.[456]

A lack of action can result in a lack of future funding

Two-thirds of all infrastructure projects in our country are paid for in part with municipal bonds, issued by more than 50,000 states, localities, and other governmental entities.[457] These bonds fund precisely the sorts of projects—seawalls, roadway elevation, sewage infrastructure upgrades, durable affordable housing—that will help communities adapt to climate change. However, within a decade, more than 15 percent of U.S. municipal debt could come from regions seeing annual climate-driven losses of up to 1 percent of GDP.[458] The market is waking up to this risk, and local governments are now facing due diligence questions about climate change when they issue municipal bonds.[459,460] Major rating agencies have issued reports warning state and local governments that their exposure to climate risk could affect their credit ratings.[461] As investors' focus intensifies and credit rating agencies begin accounting for climate risks, communities that did not invest in climate resilience ahead of time will face lower ratings and more expensive borrowing costs.[462] Before long, the communities facing the most urgent climate risks will have the hardest time funding required infrastructure adaptations.[463]

Additionally, communities vulnerable to extreme weather are already experiencing disruptions in their insurance markets. Property and casualty insurers are being hit with higher-than-expected claims as historically rare weather events grow more common and severe. As their reinsurance costs increase,[464] insurers hike customers' premiums to unsustainable levels. If they deem a high-risk community too costly to insure, they pull out of the market entirely and leave residents unable to obtain basic coverage.[465] The economic consequences for these communities are dire. In the absence of affordable insurance coverage, households and businesses have to shoulder much higher costs when disasters strike. Uninsurable communities struggle to attract and retain residents, and see their local economies deteriorate.[466] Ultimately, communities unprepared for climate-driven events may experience prolonged economic downturns.

PROGRESS AND OPPORTUNITIES

Investing in community resilience makes economic sense

Amplifying and supporting communities' successes

Communities across the country are already implementing projects that can serve as templates for others to follow, both for increasing resilience and reducing emissions. We have long known some of the ways communities can improve resiliency: elevating and siting roads and water treatment plants to avoid flooding; burying power lines to reduce outages from storms; and improving plans to reduce wildfire risk at the wildland-urban interface. But more comprehensive resilience solutions that provide many co-benefits are also available. Communities have learned that these are good investments, and that failing to act is often much more costly.[467] Still, many communities need additional support. Congress will need to provide significant new funding, and both new and existing federal funding should prioritize resilient and multi-benefit projects in every community.

NATURAL INFRASTRUCTURE. Moving beyond traditional "gray" storm water infrastructure and embracing green infrastructure solutions—green roofs, open spaces, rain gardens, permeable pavement—can reduce flooding impacts, while also reducing costs for storm water management. Unlike traditional infrastructure, which deteriorates with age and can actually aggravate flooding, nature-based solutions are self-sustaining.[468,469] Green infrastructure also provides significant community benefits like improved air quality, recreational space, lower air temperatures, shade for pedestrians, and ecosystem restoration.[470] Philadelphia is a leader in this space and is on track to implement green infrastructure solutions throughout the city as a remedy for pollution from its existing combined sewer overflow system. Rather than spending an estimated $9.6 billion to create bigger tunnels, the city opted to invest an estimated $2.4 billion in partnership with private investors to reduce the amount of storm water reaching the sewer system.[471]

> "We know that green infrastructure can be more effective, save a lot of money, and buy us time…[Most communities'] knee jerk reaction when they recognize flooding is 'we want a seawall,' but we need to help people work through to understand the gains that can be had from green infrastructure."[512]
>
> **—Alice Hill**
> *Senior fellow for climate change policy, Council on Foreign Relations*

Many of the same strategies for reducing flooding can also help urban communities when temperatures rise. Green roofs, open spaces, and trees all help reduce the heat island effect in cities and provide benefits to energy customers. For example, a study of Chicago found that increasing tree cover by 10 percent could lower total home energy use by 5 to 10 percent annually.[472] Trees also reduce storm runoff, reduce air pollutants, and sequester

carbon, and communities with more trees have higher home values. Ecosystem restoration of habitats, such as dunes, wetland, oyster reefs, and mangroves, can also considerably mitigate flooding impacts. The economic benefits can be significant. For example, implementing cost-effective, nature-based solutions to flooding along the Gulf coast can avoid more than $50 billion in future impacts.[473] These habitats provide other co-benefits such as carbon sequestration in wetlands and water quality improvements from oysters.

MICROGRIDS. Maintaining electricity during an emergency can be a life-or-death matter, especially when it comes to critical services like hospitals and fire and police stations. Microgrids can help maintain essential services, while also providing benefits to whole neighborhoods. Neighborhood microgrids operate within the larger community-wide grid, but can "island off" in times of crisis like storms, providing a more resilient power supply within communities. Microgrids provide even more benefits when paired with high levels of renewable, distributed energy generation. Rooftop solar and community renewables, when tied to a microgrid, vastly improve energy reliability and can reduce costs, which benefits low-income communities in particular.[474] The Western Alaskan town of Kipnuk, for example, made a successful transition from primarily diesel power to a microgrid consisting of wind turbines, electric heating systems, and dispatchable diesel energy for times of undergeneration.[475] This transition resulted in reduced greenhouse gas emissions, cheaper energy costs, and a more reliable energy system for the community.

SMART GROWTH. Putting housing and destinations like grocery stores, restaurants, and other businesses close together in urban areas can significantly reduce emissions by promoting walking, biking, and transit for shorter trips. In fact, making existing large cities more compact and connected can reduce transportation emissions by up to 35 percent.[476] Concentrated development, often referred to as "smart growth," has numerous co-benefits. It supports businesses and boosts property values, and infill development makes better use of investments in utilities, roads, and other city services. Public infrastructure construction costs can be cut by a third, and ongoing public services costs decreased by 10 percent.[477] Investing in a compact and walkable town center has led to resilient revivals of many communities, like Florence, Alabama, where a Main Street restoration resulted in new economic development to the area and an increased tax base. The Kentlands neighborhood in Gaithersburg, Maryland, has also been recognized for its range of housing options for different income brackets, along with ready access to groceries, businesses, and a variety of community services and amenities in a walkable range.[478] However, cities must take steps to ensure that long-time residents are able to remain in their community and benefit from these investments. East Palo Alto and parts of San Francisco have shown that workable anti-displacement policies exist; communities just have to commit to implementing them.[479,480]

SMART AND EFFICIENT BUILDINGS. Communities can also reduce emissions by changing how buildings are constructed and run: smart buildings, energy efficiency, increased electrification, and improved weatherization are all needed. The movement towards smart buildings can decrease greenhouse gas emissions from the commercial and residential building sector, while also saving businesses and consumers money by lowering overall energy use. Smart buildings combine highly energy-efficient appliances and equipment with advanced control technologies that maximize energy efficiency. By automatically

optimizing building operations, like heating, air conditioning, lights, security, and ventilation, and even transportation, smart buildings can minimize energy use and save water resources while maintaining building functionality. Intel's office in Petah Tikva, Israel, is a renowned smart building that employs 14,000 sensors to monitor building services, resulting in a 40 percent increase in energy efficiency and a 75 percent reduction in water use over a typical office building.[481] In the United States, the market for smart building systems is growing[482] thanks in part to programs like Energy Star, a joint endeavor of the Environmental Protection Agency (EPA) and Department of Energy (DOE) that labels top-performing smart building equipment. Since 2010, Energy Star has helped U.S. consumers and businesses save $18 billion on energy costs and avoid emissions equivalent to 33 million cars on the road.[483]

Building electrification can be another source of significant emissions reductions. Seventy million American homes and businesses burn natural gas, oil, or propane on site to heat their space and water, generating 560 million tons of carbon dioxide each year.[484] Unless a grid is heavily powered by coal, switching to electric heaters or water heaters reduces carbon emissions immediately. Solutions for electrification are already widely available and cost competitive in many cases.[485] Additionally, weatherization upgrades reduce emissions and save households on average $283 or more every year and return $2.78 in non-energy benefits for every $1.00 invested.[486] These savings are critical for lower-income households, which spend a significantly higher percentage of income on energy costs.[487] Reducing this burden can improve health and increase household disposable income, with important local economic multiplier effects.[488] Cities nationwide, from Reno, to St. Louis, to Pittsburgh, to Boston, are already adopting more climate-friendly codes for residential and commercial buildings.[489]

HONOLULU'S RESILIENCE PLAN: BUILDING SAFE AND SECURE COMMUNITIES

The island of Oahu faces significant climate threats from sea-level rise, coastal flooding and erosion, and hurricanes. So it is no surprise that Honolulu is committed to improving its resilience to climate impacts. The city is developing both climate mitigation and climate resilience solutions, and they are doing this with the engagement of the community.[513] In his testimony to the Special Committee, Honolulu Mayor Kirk Caldwell described the importance of community engagement: "With contributions by…thousands of residents, hundreds of organizations, and dozens of business and non-profit leaders, this is truly a shared vision for a resilient island future. It is our community roadmap that shows us what we need to do, where we need to go, and how to get there."[514]

The Oahu Resilience Strategy features a broad set of projects, policies, and goals that will help the community survive, adapt, and thrive in the face of significant climate-induced shocks and stresses. Importantly, the plan takes a holistic view that not only emphasizes resilient infrastructure and emissions reductions, but also addresses affordable housing and living expenses to ensure communities stay intact. The plan recognizes that "community is the essential element of resilience" and develops ways to improve social connections to help communities respond to extreme events. As Mayor Caldwell said: "Our policies need to be bold. If we want to save the things we love most about our local community, ironically, we have to change."

Access to funding is the key to a resilient, cleaner future

Money spent now will save lives, reduce the need for post-disaster recovery funds, provide returns throughout society and the economy, and avoid even steeper costs in the future. To achieve these gains, the federal government and states need to rethink the current infrastructure decision-making framework and how overall costs and benefits are calculated for individual projects. Funding decisions must account for a project's lifetime resiliency benefits, rather than the lowest upfront cost.

Increasing and coordinating federal spending to support resilience

Every year, the federal government spends billions of dollars on community infrastructure and development, but it can do much more to incorporate resilience priorities into these existing projects and programs. For example, within EPA's Clean Water State Revolving Fund and Water Infrastructure Finance and Innovation Act programs, more emphasis can be placed on innovative green infrastructure, water, and energy efficiency projects, building from the already successful Green Project Reserve Program.[490] The U.S. Army Corps of Engineers should, where appropriate, continue to shift away from an exclusive focus on traditional flood control infrastructure, like levees and dams, and towards nature-based solutions. Programs like the Department of Housing and Urban Development's (HUD) Community Development Block Grants should incorporate resiliency and smart growth strategies to incentivize improved development. Resilience consideration should be a prerequisite of all Department of Transportation (DOT) highway and transit funding decisions. And grant and formula funding should be made available by the Federal Highway Administration for states, localities, and Tribes to reduce their risk before disaster strikes.

Previous programs that increased coordination and resilience funding across all federal agencies enjoyed broad support in the communities that participated. In particular, the Sustainable Communities Initiative (SCI) was an innovative, interagency collaboration among HUD, EPA, and DOT. A review of the program stated, "the SCI has created one of the largest integrated approaches to urban planning in a generation – at last, communities are threading the pieces together, realizing the opportunities to link their goals and strategies for jobs, housing, transportation, environmental, and equity."[491] We need to create and fund programs with the same goals as the SCI to establish a repository of shared knowledge and resources for at-risk communities.

Incentivizing action at the community level

Federal funding should also incentivize communities' actions to improve resilience. Congress could encourage the development of progressive standard building codes for efficiency and resiliency. Progressive codes could promote net-zero emissions buildings, but also ensure that builders across the country are using materials and meeting performance standards to withstand increasingly severe floods, hurricanes, and wildfires.[492] New sources of federal funding could then be used to reward communities that adopt such codes, supporting communities that are building for the future. Additionally, Congress can provide tax incentives or financial assistance that leverage private funds for retrofitting old buildings.

The Federal Emergency Management Agency (FEMA) already offers incentives to communities by discounting flood insurance through its Community Rating System.[493] This voluntary program allows communities to lower their flood insurance rates by undertaking community-wide flood mitigation efforts that exceed the National Flood Insurance Program's (NFIP) minimum requirements. But additional incentives are possible. Congress could also encourage FEMA to reconsider implementing a Public Assistance Deductible, which would establish an amount of disaster funding a city would have to cover before federal funding kicks in. The more a city does to improve its resilience, the lower its deductible. Other innovative approaches to encourage proactive resilience spending could build from the example of the Federal Cost Share Reform Incentive, which allows post-disaster federal cost-share with states to increase from 75 percent to as high as 85 percent, based on factors like adopting and enforcing the latest building codes.[494] Congress should considering creating new incentive programs for cities that adopt more resilient zoning codes, including additional rewards for communities that zone low-income housing in low-risk areas or those that prioritize appropriate infill development.

FROM VACANT LOTS TO GREEN COMMUNITIES: SAINT PAUL'S TRANSFORMATION

Saint Paul, Minnesota, is capitalizing on a major opportunity to build sustainable and energy efficient neighborhoods that grow jobs and increase housing. The closure of a Ford Motor Company assembly plant left more than 120 acres of prime real estate empty in the middle of a higher-income city neighborhood. A local developer is now working closely with the city and community to redevelop this site with dense, mixed-use development that includes office and retail space, as well as thousands of units of housing at all income levels. The group is working with Xcel Energy to guarantee that 100 percent of the electricity at the site will come from renewable or carbon-free resources. The lot will also feature 55 acres of public space, including four new city parks and other green space that will be designed with storm water management in mind.[515] This infill development is projected to lower energy costs, provide clean air and water, and raise property values in the area.[516,517] Mayor Melvin Carter called the endeavor "probably one of the biggest undertakings that the City of St. Paul has ever taken on."[518]

Helping communities through technical assistance

Communities—especially low-income and small communities—need support to develop resilience projects. Future funding should promote innovation while providing communities the data and expertise they needed to identify opportunities for themselves. Armed with the right information, communities are better able to assess their risks, engage local populations, and develop projects that address their specific needs. Increasing technical assistance to communities nationwide can build a new pipeline of innovative resilience projects.

Developing creative financing mechanisms

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Direct federal funding should only be part of the solution. Communities can pursue financing mechanisms like environmental impact bonds, green bonds, and climate bonds, which appeal to investors who may be willing to accept slightly higher prices to promote broader environmental outcomes. Yet, not all communities have the resources to issue their own debt, meaning other avenues of financing need to be developed and expanded. And while many communities feel unable to take on additional debt, others are already employing new approaches to servicing debt related to community resilience projects. Of particular note, some communities have realized that funding to service such debt can come from a city's existing budget, since resilient designs have lower operations and maintenance costs over time. Lessons from these leading communities need to be shared broadly so local and regional governments can identify opportunities for innovative financing mechanisms. The federal government could also create lending institutions with the expertise to understand the full costs and benefits of proposed resilience projects, with a focus on ensuring equality in lending to low-income communities. This could be through new resilience-focused infrastructure banks or revolving loan programs. State-level banks have already proven successful, leveraging an average of $3.4 in private capital for every $1 of public investment.[495]

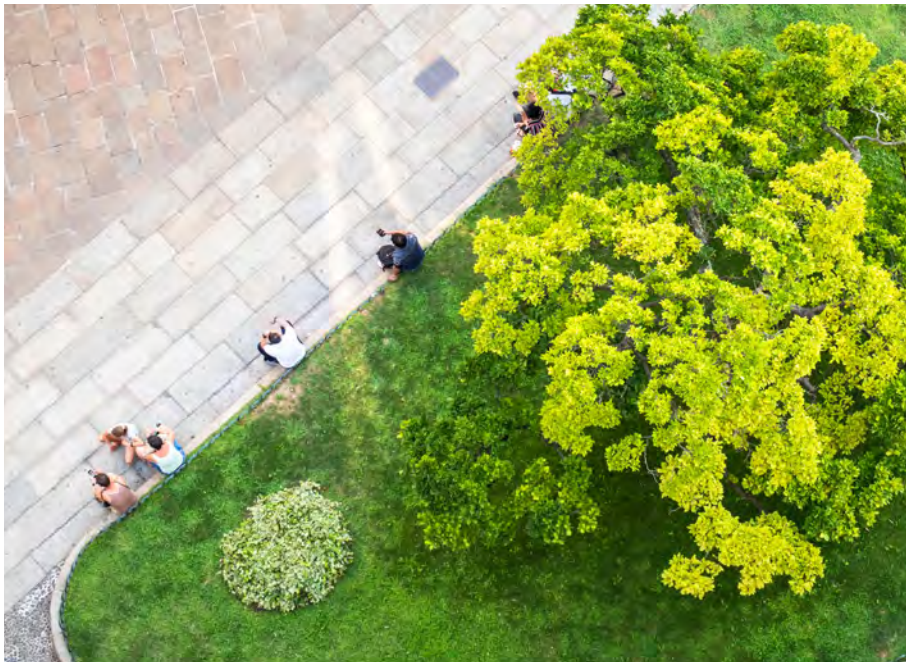
Empowering individuals to invest in their own resilience

Low wages and high living costs leave little ability for Americans to save for disasters: 40 percent of Americans are unable to cover a $400 emergency expense.[496] U.S. economic fragility has attracted the attention of government agencies usually less concerned with household financial well-being. FEMA included "financial preparedness" in its most recent strategic plan.[497] Such an acknowledgement should be a call for greater federal action to empower individuals to invest in their own resilience. For example, a refundable resiliency tax credit, point of sale credit, or reimbursement through block grants could increase people's ability to prevent disaster-related expenses by enabling proactive spending to make their home more secure or take other preventative action.

Effective, reliable recovery policies are resiliency strategies

Effective and reliable disaster recovery polices increase resilience—by rebounding stronger after a catastrophe, people are better poised for future disasters. A better disaster recovery framework aimed at individual and community recovery would help the whole country be more resilient.

Reliable recovery funding can help communities plan for the worst. For example, permanently authorizing the Community Development Block Grant-Disaster Recovery (CDBG-DR) program would be a major step forward. This program takes the existing flexible framework of CDBG and, on an incident-by-incident basis, injects it with more funds and alternative regulations to fund long-term disaster recovery and mitigation. However, CDBG-DR is not invoked for every major disaster declared under the Stafford Act, so communities do not know what aid will be available to them during the next event. With a stable framework in place through permanent authorization, communities can better understand and plan for federal government backing in their time of need.



Relief should also target low-income communities through direct cash assistance to individuals and families and grants and low-interest loans to institutions. Cash assistance guarantees speed and flexibility in the aftermath of crises. For years, evidence has grown of the effectiveness of cash assistance relative to in-kind aid.[498] Cash offers people the freedom and dignity of choice to use their resources for housing, food, medicine and medical care, work expenses, transportation, or other needs.[499] It also empowers people to jumpstart the local small business economy. Further, in an environment of deteriorating social programs, automatic triggers and simple eligibility thresholds would allow for rapid deployment of assistance.

The federal government should also explore all avenues to infuse capital into institutions that serve low-income communities recovering from climate disasters. Community Development Financial Institutions (CDFIs) are a proven vehicle for speeding recovery. CDFIs offer financial products and services to low-income populations, which are often under-banked and suffer from a lack of investment. An emergency fund to get money into these institutions in times of disaster would provide a welcome safety net to these households and businesses.

Federal reforms should promote resilience

Evolving the NFIP framework in a changing climate

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Growing risks demand an insurance framework that helps keep people and property out of harm's way, and helps them recover quickly when disaster strikes. The National Flood Insurance Program (NFIP) currently subsidizes risk for too many wealthier owners of water-front property, while covering too few of the poorest and most vulnerable. As the waters—and the risks—rise because of climate change, the country has struggled to agree on a fair way forward. In the meantime, the number of Americans living in these high-risk areas has climbed 14 percent between 2000 and 2016.[500]

Changes to the NFIP programs are needed to address existing structures in the flood zone, but primarily to avoid new development in areas of elevated flood risk. Laura Lightbody of the Pew Charitable Trusts testified before the Special Committee that, "While a reformed NFIP may still need to offer assistance to those currently living in risky areas, whose homes were built years ago, it should not be used to buy down the true costs of new development in risky areas."[501]

Any reforms must recognize and mitigate the historical inequities of housing policy that have pushed poorer populations and communities of color into riskier areas, and the decades of disaster recovery policy that have failed to make communities whole. Any reforms must also consider ways to assist Tribal communities and multi-generational rural communities. Furthermore, buying out homeowners in flood-prone areas has been one of the most cost-effective approaches to reducing flood risk in communities.[502] However, completing buyouts is difficult and can be excruciatingly slow for homeowners looking to leave. The federal government should dramatically expand and streamline buyout programs to give people a fair option to leave their homes and move to safer areas.

Improving resilience through secure housing

Too many Americans are experiencing homelessness or paying too much of their monthly income on housing, leaving them more vulnerable to climate risks. Before the coronavirus outbreak, even in what was viewed as a strong economy, 15 percent of U.S. households paid more than 50 percent of their income on housing, and 30 percent paid more than 30 percent of their income.[503] At least another 500,000 people were experiencing homelessness.[504] High housing costs make it hard to make ends meet, let alone save for an emergency. Instead, when disaster strikes, people's lives are severely disrupted and they are often displaced in the recovery process. These outcomes are avoidable. The financial and physical resiliency of low-income Americans across the country could improve with increased federal investment in housing assistance. Taken out of harm's way, people will be empowered to improve their families' and communities' resilience themselves. When people are secure in their housing, they can better prepare for climate risks.

Understanding risk requires better data

More and better data and analytical power are available every year. The federal government should ensure that all levels of government have the best information possible to inform risk-based resilience and recovery strategies before and after incidents.

Tailored data for communities is essential to improve how they identify risks and opportunities. Scientists are increasingly able to "downscale" global climate models to predict impacts in specific communities, but policymakers in those communities don't always know these data exist or how best to use them for risk assessments. A more coordinated federal approach to sharing climate data is needed. As former National Security Council director for resilience policy, Alice Hill, testified before the Special Committee, "Although decision-making tools and databases rest on numerous federal government websites, it is hard to imagine how busy local officials and small business owners can make sense of them without guidance as to their merits and applicability."[505]

While current programs do exist to provide climate services, more federal resources must be applied to fill the knowledge gap at the local and state level. Programs like the U.S. Drought Monitor provide pivotal mapping tools for federal, state, and local governments to plan drought response measures and trigger disaster declarations when needed.[506] NOAA also provides an array of other valuable mapping tools, data, and educational materials to help officials make climate-smart decisions and plan for a warmer future,[507] and the Regional Climate Adaptation Science Centers provide invaluable local expertise and regional climate knowledge.[508] These programs must all be supported and expanded, and their products made accessible to decision-makers across the public and private sector.

Further, we need increased investment in better risk assessment and modeling. In particular, FEMA flood insurance maps no longer represent a credible assessment of risk for many communities across the country.[509] Within our changing climate, historical data are insufficient to project future risk. Instead, we need to incorporate our best climate projections that take into account future sea-level rise and inland flooding into FEMA flood risk maps.

And finally, we need to communicate better. Anecdotes abound of U.S. cities and towns facing multiple 100-year or 1,000-year floods in quick succession, which speak to the increasing risk communities are facing. But a challenge remains to truly convey what it means to buy a house in a "flood zone." Living in an area that may flood once every hundred years sounds different from buying a house that has a 30 percent chance of flooding within the lifespan of a 30-year mortgage. Increased investments to improve communication can build from previous successes and help people better understand and quantify what climate risk means to them.

Environmental Justice Priorities

While all Americans will feel the effects of environmental degradation and climate change, certain communities have historically borne the brunt of pollution—and they will continue to, unless we consciously reverse the policies that have entrenched this discrimination. Generations of economic and racial inequality have disproportionately exposed workers, communities of color, and Indigenous people to low wages, toxic pollution, and climate threats.[519,520,521] In one of many examples, research has found that pregnant women exposed to high temperatures or air pollution are more likely to have premature, underweight, or stillborn babies—a trend that harms Black mothers and babies at a much higher rate than the broader population and has repercussions for the long-term health and economic opportunities for Black families.[522] Economic insecurity, poor health outcomes, and a lack of political representation exacerbate each other, holding back people in polluted communities and making them more likely to suffer the same injustices in the future.

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It is not a coincidence that communities of color deal with higher cumulative health burdens of pollution and increased impacts from climate-induced disasters. It is the direct result of systemic racism, manifested in discriminatory real estate and banking practices, restrictive local zoning, unequal access to transit, chronic underinvestment, and other social, economic, and health injustices. Policymakers have a responsibility to acknowledge this devastating legacy and also to recognize that prior climate legislation has not been successful in mitigating the unique, systemic impacts to these communities.

Moving forward, Congress must work to rectify this legacy of injustice. This means ensuring regulations are in place to reduce pollution and dedicating a significant portion of direct climate investments for these communities. It also means committing to engage frontline communities as full partners in the development of climate solutions. By listening to and working with environmental justice (EJ) leaders, Congress will be better able to provide the tools communities need to become more climate resilient, mitigate future climate change, and protect themselves from toxic pollution, which will in turn improve public health and economic security.

The EJ movement seeks to address these racial and socioeconomic inequities and achieve equal protections and an equal voice for all communities, especially those harmed most by pollution. Common goals promoted by EJ organizations include: providing universal, affordable access to safe drinking water and clean energy options for low-income communities; conservation of waters and habitats that protect and provide for communities; funding for workforce development in clean energy, environmental restoration, and reclamation; improving community climate resilience; and ensuring that environmental impact assessments for major projects include analyses of racial equity and cumulative effects of environmental harms.

The Special Committee partnered with the Senate Environmental Justice Caucus and the Senate Environment and Public Works Committee to solicit feedback from leaders of the EJ movement on how to best address climate impacts in their communities.[523] The committees asked about which existing federal programs have helped EJ communities with climate mitigation and resilience efforts, the barriers these communities face in achieving environmental justice, and what actions the federal government should take next. Below are some of the suggestions the committees received.

Environmental justice leaders' input to the Special Committee

- **Increase funding for EPA Brownfields Environmental Workforce Development and Job Training.** Include workers and program administrators from affected communities, as well as people of color.
- **Set aside a portion of all federal water infrastructure funding to assist in the development of firms and contractors of color.** Build capacity within EJ communities to compete for green infrastructure and green energy bids.
- **Direct federal agencies to reverse course on the Trump administration's rollback of important public health and environmental safeguards.**
- **Increase EPA enforcement of all rules and regulations, especially those governing industrial facility pollution into surrounding EJ communities.**
- **Renew EPA's Office of Environmental Justice and fund programs that address EJ concerns.** Under the Trump administration, community grant allocations for environmental justice projects have fallen 70 percent. The EPA must also continue to update, expand, and publish new versions of EJScreen, an important environmental justice mapping tool that protects low-income communities.
- **Invest in affordable, safe housing in all communities.**
- **Amend the Stafford Act** to prioritize federal disaster assistance to the lowest-income survivors of natural disasters first, to ensure an equitable recovery.
- **Ensure that families displaced by natural disasters can participate in the planning and management of their return or relocation.**
- **Establish new community grant programs** that invest in climate resilience planning, pre-disaster resilience, building retrofits, mitigation, and microgrid development in EJ communities.
- **Increase funding for the Low Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP).** These programs subsidize energy costs and facilitate energy efficiency improvements for millions of low-income households across the country.
- **Make the renewable energy investment tax credit (ITC) and production tax credit (PTC) direct payments to reduce barriers to clean energy in EJ communities.** EJ communities are often unable to access clean energy incentives like tax credits because the credits require tax liability. Incentives must be restructured to allow low-income individuals and communities to benefit, rather than just large developers.
- **Invest in innovative decentralized energy distribution systems that are community-owned and governed.**

- **Ensure that renewable energy and energy efficiency demonstration projects are implemented in vulnerable and frontline communities.**
- **Scale up investment in public transit, zero-emission buses and trucks, and affordable electric vehicles and charging infrastructure.**
- **Authorize community solar and other community renewable projects nationwide, rather than relying on state authorization.** Currently, EJ community residents are often unable to switch to clean energy because they live in multifamily homes or rent. They may also face challenges accessing credit to cover upfront costs.
- **Fund a national Green Bank to provide financing options and direct grants for clean energy and climate resilience projects.**
- **Maintain climate considerations as a provision of the National Environmental Policy Act (NEPA) for major infrastructure projects.**
- **Fund and expand programs that help impacted communities navigate the decarbonization transition; create new jobs in the clean energy and environmental conservation and restoration sectors, and provide interim community services.** Existing programs include the Appalachia Regional Commission's POWER Initiative, EDA's Assistance to Coal Communities, USDA's Rural Business-Cooperative Service, the Treasury's CDFI Fund, DOI's Office of Surface Mining Reclamation and Enforcement, NIST's Manufacturing Extension Partnership, and SBA's Regional Innovation Cluster Program.
- **Increase funding for coastal repairs, relocation, and habitat restoration in the Great Lakes region.**
- **Require cumulative impact assessments and racial equity assessments** before permits for new polluting activities can be approved.
- **Fund EJ equity research to ensure that climate change mitigation policies do not perpetuate or exacerbate inequalities.**
- **Leverage federal funding for research into the cumulative public health effects of toxic pollution.** A 2017 National Academies of Sciences study on health risks for people living near surface coal mine sites was canceled by the Trump administration before completion.

Dr. Cecilia Martinez, the co-founder and executive director of the Center for Earth, Energy and Democracy, highlighted to the Special Committee the importance of working with EJ leaders to develop comprehensive climate legislation that works for all Americans:

> The shift to a non-greenhouse gas future will require substantial new forms of capital investment by both the public and the private sectors to build a new national infrastructure as well as democratic community participation to help set infrastructure investment priorities. Unless justice and equity are central components of our climate agenda, the inequality of the carbon-based economy will be replicated in the new economy.[524]

Environmental justice is not an 'add-on' to the climate debate. It is a critical component of any and all legislation that seeks to address the climate crisis and improve American lives.

FARMERS AND RURAL COMMUNITIES

> In their work to provide food and fiber for our families and the world, farmers and ranchers are already deploying a range of conservation solutions that also sequester carbon and reduce emissions. More of this important work can be encouraged through targeted funding, support, and coordination structured to generate new revenue and support rural communities.

American farmers and ranchers feed our country and the world. A strong and resilient agriculture sector is crucial to our national security and economic prosperity, especially in rural America. Our farmers are the stewards of a large portion of land in the United States, and they care deeply about the health of the land they work. As we now face the challenges of climate change, farmers and ranchers can be a vital part of the solution. Fortunately, farmers have been piloting techniques for years to improve soil health, conserve water supplies, reduce emissions, and increase overall resiliency. As a result, new opportunities are emerging: some of these practices have the potential to generate new income streams to stabilize farm financials in these incredibly difficult times.

In the last several years, farmers and ranchers have faced enormous market challenges, low margins, growing debt, and dramatic shifts in demand for their products. Rural communities are seeing substantial economic challenges from low commodity prices and disruptions to international trade brought on by shortsighted tariffs.[525] Their future is now even more uncertain due to the impact of more frequent and extreme weather events.

The devastating consequences of new extreme conditions, like record floods, droughts, and catastrophic wildfires, are already impacting farmers and ranchers. These events can wipe out crops, stress and kill livestock, and threaten their businesses' survival. In 2019, unprecedented levels of rain prevented farmers across the Midwest and Great Plains from planting their crops on time, resulting in a shortened growing season and smaller yields.

Nationally, federal crop insurance programs paid a record $4.2 billion in claims for the 19.4 million acres that could not be planted that year.[526] Altered precipitation patterns have wreaked havoc on Western agriculture, where devastating multi-year droughts in California have stressed the rural economy and had impacts across the state in small towns and large cities alike. In 2015 alone, the state lost $1.8 billion in agriculture revenue and nearly 21,000 jobs to severe drought.[527] These climate impacts also affect suppliers, farm equipment manufacturers, distributors, and more. The expansive economic reach of climate impacts across farming supply chains poses a threat to the social and economic vitality of rural communities and way of life in small towns across the United States.

America's farmers already have many of the tools they need to improve productivity, increase resilience to extreme events, and generate new income. Advanced biofuels and biomaterials are being developed as alternatives to synthetic plastics, building on the opportunity demonstrated by ethanol to continue lessening our dependence on fossil fuels. Certain farming and ranching practices can also draw significant carbon from the atmosphere, and when this service is assessed a value, it can mean new income for farmers and ranchers. The data show that these soil-enhancing practices can also make farms more productive and resilient to flood and droughts. Expanding methane capture, the use of tailored livestock feed mixes, and precision farming aided by satellites, broadband data, and sensors can substantially reduce both emissions and production costs from our working lands. These advancements and others, when used at scale, can make farms more profitable while helping fight climate change.

"Every day, farmers, ranchers and private forest owners make stewardship decisions that impact over 1.4 billion acres of non-federal rural lands—or over 70 percent of the landmass of the contiguous 48 states. On-farm conservation is not just a good solution for helping solve the climate crisis, it also supports a stronger rural economy through increased resiliency and profitability for farmers and ranchers. Working with these farmers and ranchers is the quickest, most scalable and most economically feasible solution to lowering greenhouse gases."[608]

— Land O' Lakes, Inc.
Communication to the Special Committee

The federal government can and should facilitate this transition by promoting stable markets, providing incentives and financial support to implement best practices, and delivering accessible, science-based decision-making tools. Specifically, Congress should:

- ✔ Expand existing USDA agricultural conservation programs and include improved soil health and soil carbon storage incentives.
- ✔ Invest in technical assistance and expand apprenticeship programs to support farmers and ranchers as they adopt and expand regenerative practices.
- ✔ Facilitate participation in carbon markets by supporting research and development of accurate, low-cost, readily scalable methods to measure soil carbon.
- ✔ Provide funding for research, development, and deployment of advanced biofuels and bio-based products from waste products and non-food crops.
- ✔ Provide technical assistance and financial incentives to scale the use of methane digesters.
- ✔ Fund grants, incentives, and tax credits to assist with the costs of building on-farm clean power generation and reduce the costs and technical barriers of connecting to the grid.
- ✔ Invest in and maintain state-of-the-art universal rural connectivity, including rural broadband.

These actions will ensure the United States remains a world leader in sustainable agriculture and will help preserve the rich cultural heritage and socioeconomic resilience of our rural communities. Providing clear economic incentives and locally tailored guidance will enable farmers and ranchers to make necessary changes on a scale and at a speed that matches the climate challenge.

THE RISKS OF INACTION

New extremes will challenge productivity

As climate change accelerates, farmers and ranchers will experience new weather extremes that challenge their ability to provide food, fiber, and fuel for the nation. While extreme weather events cause measurable macroeconomic effects—namely, decreases in saleable crops and rising food prices—the effects on individual agricultural producers are often more acute and devastating. Extreme weather events will increasingly jeopardize the lives, livelihoods, and futures of farm families. If we do not curb greenhouse gas emissions and reduce the impacts of increasing droughts, heatwaves, and catastrophic wildfires, by 2050 American agriculture is projected to lose the last 30 years of progress, returning to the productivity levels of the 1980s.[528]

DROUGHTS AND HEATWAVES. With average global temperatures on the rise along with altered precipitation patterns, climate change is making droughts longer, more common, and more severe in certain U.S. regions, including the Mountain West and Southwest.[529] Among natural disasters, droughts trailed only severe storms and hurricanes in total damages since 1980,[530] with most of those losses coming from decreased agricultural productivity. In this timeframe, U.S. farmers and ranchers have seen 27 individual droughts with losses over $1 billion, totaling a staggering $253 billion in damages, or about $6 billion per year. That figure is equivalent to losing about 5 percent of annual agricultural GDP.[531]

Droughts harm overall agricultural output by lowering crop productivity. And, to combat the loss of soil moisture, farmers are often forced to expand their irrigation activities to maintain adequate yields. Agriculture is already the world's leading user of water, and during times of drought, the sector contributes to greater water scarcity by drawing down groundwater levels for irrigation. This imposes significant monetary costs on both the farmers and the other sectors in communities that rely on that water supply.[532] In the central and southern Mountain, Pacific, and Great Plains regions, by 2060 there may be between 20 and 50 percent less surface water available for irrigation.[533] Water scarcity is a nationwide problem: 40 out of 50 state water managers surveyed in 2014 expected water shortages somewhere in their state over the following decade.[534] With more frequent droughts and severe water shortages, farmers and ranchers will face steep competition for access to water resources, while requiring more water to ensure the same level of productivity—a major challenge for consistent profitability.

Heatwaves, even in the absence of drought, can cause steep drops in global production of staple crops like corn.[535] During years with significant heatwaves, countries see cereal

production drop by 9 percent on average, rivaling the 10 percent drop seen in major droughts. Heatwaves also cause significant physiological stress on cattle and represent a threat to animal health and dairy productivity.[536,537] In June 2017, a few counties in Central California recorded nine consecutive days over 100 degrees Fahrenheit, resulting in the deaths of over 4,000 cattle.[538] And, in 2011, Iowa ranchers recorded 3,500 heat-related cattle deaths during the month of July when the heat index rose above 110 degrees Fahrenheit for three consecutive days.[539]

CATASTROPHIC WILDFIRES. Already, climate change has increased the incidence of catastrophic wildfires and extended the fire season, especially in the West.[540] These wildfires can decimate farms, ranches, and working forestland and destabilize rural economies. A 2017 fire outside Amarillo, Texas, burned nearly 500,000 acres of pasture land, resulting in $21 million in damages.[541] Agriculture businesses can take up to a decade to recover from these events.[542] In addition to direct fire damage, some products like wine grapes are particularly vulnerable to smoke damage. Even if a grape vine itself is not damaged or burned, winemaking grapes exposed to significant smoke usually cannot be used in wine due to change in flavor, resulting in significant losses for vineyards. The devastating 2017 wildfires that engulfed California's Napa and Sonoma valleys caused an estimated $1 billion in damages.[543]

FLOODS. In the upper Midwest, the frequency and intensity of precipitation is projected to continue increasing, leading to greater incidence of costly flooding.[544] The Midwest already faced an extremely wet spring in 2019, delaying planting across the region. Ohio, Indiana, and Illinois saw five months of persistent heavy rain and flooding that substantially delayed the planting timeframe for corn and soybeans. This resulted in decreased yields and billions of dollars in lost agriculture production, and led to price increases for corn, corn-based cereals, and ethanol.[545] Flooding can stunt the growth of crops, and even after flood waters recede, newly introduced diseases can hurt crop yields. In addition, beneficial soil microbes and fungi must be re-established to maintain soil health and recover productivity, a costly and time-consuming process.[546] The nation's supply of commodity crops is increasingly at risk from severe flooding across the Missouri and Mississippi River basins.[547] These price increases will be passed on to the American consumer or further squeeze the margin farmers make on their crops.

"Improvements in soil health can also yield benefits at a watershed scale. Increased water retention in soils can reduce regional flood risks, which in turn means less federal disaster funding. Improvement in soil health can also improve water quality downstream, reducing costs for regional and rural water treatment plants and ultimately, reduce pollution in waterbodies like Lake Erie or the Gulf of Mexico.

In addition to the environmental benefits of investing in soil health, these investments also have a strong economic benefit for the farmers and the rural communities surrounding them. For example, as more farmers adopt cover crops, more businesses will spring up to supply seed, provide agronomic advice, and help with management of cover crops. Similarly, it has the potential to drive further investment in infrastructure, such as broadband, if there is a market demand and need for these investments, such as with increased adoption of precision agriculture techniques. These new opportunities can mean new jobs for struggling rural economies."[609]

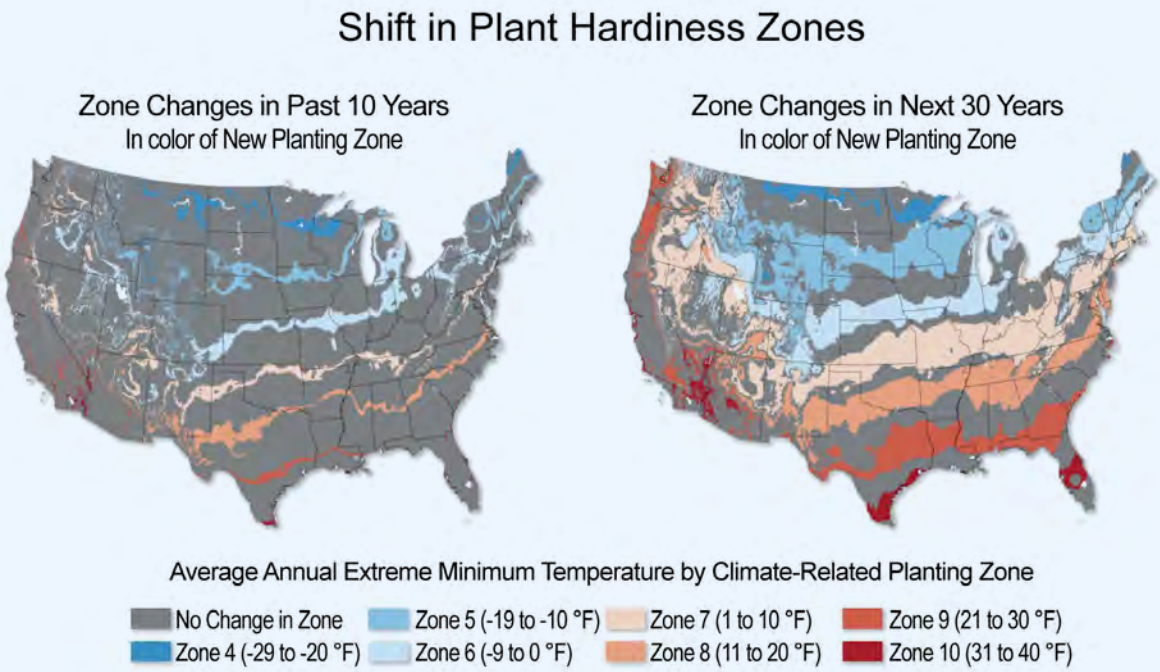
— Cargill

Communication to the Special Committee

Long-term changes will create a "new normal" for many farmers and ranchers

Shifting growing zones

Farmers located at the geographic edge of a climate suitable for producing a certain crop may find that crop no longer viable. For farms with the capital and knowledge to adapt, this means cultivating a new crop or a new variety better suited to changing local conditions. But for others who lack these resources, these changes could be insurmountable. As climate change accelerates, hardiness zones in the United States will shift northward, requiring faster reorientation of farmland and farm resources to crops adapted to the changes in local growing conditions.[548]



Source: NOAA

Battling new pests and disease

As regional climate zones shift, warmer weather will enable new pests and diseases to appear in new areas.[549] For example, the northward shift of the habitable range for tick species may prove costly for livestock producers, as ticks carry many damaging diseases like Cattle Fever.[550] This will result in greater yield losses and impose additional costs on farmers forced to invest in new practices and products to protect their livestock and crops. Additionally, changes in rainfall, temperature, and relative humidity can promote the growth of fungi that produce potentially fatal mycotoxins in staple foods like wheat, rice, and corn, ruining the crops.[551] Bees and other pollinators that are essential to the cultivation of many crops are also vulnerable to shifting habitat zones, and agriculture may be adversely affected with their departure from certain regions of the country. This is especially true if the insect populations migrate more rapidly than farmers shift their crop varieties.[552]

Protecting soil health

Producers are confronting increased soil erosion due to frequent, intense rainfall.[553] Rich soil formed over hundreds of years can erode in a matter of minutes and is not easily replaced. The cumulative impacts of even a few extreme rainfall events on soil can be significant. Previously eroded areas are often more vulnerable to additional erosion in later rain events, creating a management challenge for farmers and downstream farms and communities. Higher air temperatures predicted across arid regions will also further decrease soil moisture and increase potential evaporation rates, resulting in significant negative effects on crop production and native rangeland.[554] Increasing soil health has been identified as a key strategy for reducing greenhouse gas emissions, in addition to improving yields. So farmers may face a race against time to increase soil heath as climate change threatens to decrease it.

Safeguarding agricultural workers

With global average temperatures rising, agricultural workers are already facing more days with heat stress that endangers their health. Farm labor is intense work and avoiding the elements is often difficult or impossible. For outdoor workers, heatstroke is a constant threat, and workers must be given adequate shelter and rest on hot days to avoid heat-induced injury and death.[555] Even with precautions, labor productivity during very hot work periods will still drop.[556] Adapting farm work for a hotter environment will be key to protecting the health and productivity of workers.[557] Strong labor provisions must be implemented as the climate warms to avoid harm to the people who plant, grow, and harvest our nation's food.

"Natural resource concerns, cropping rotations, pest pressures, and climate vary across the wheat growing regions of the United States. Understanding those differences and recognizing that not all farming operations are the same is important and relevant for wheat production as it is grown in 42 states. The conservation activities or changes to management practices that growers implement on their farm can be costly initially, sometimes requiring new equipment and changes in farming practices with uncertain impact on a producers' crop yield, crop quality and ultimately the price received for the crop."[610]

— National Association of Wheat Growers

Communication to the Special Committee

Growing specialty crops in a changing climate

Many specialty crops offer farmers higher profit margins and generate significant economic value for rural economies. As a result, federal programs and legislation have often encouraged their adoption.[558] While these crops, which represent an almost $80 billion industry,[559] tend to bring in larger revenues, they are also more sensitive to climate changes.[560] Since the geographic range of production for specialty crops is often small, even localized weather events like a damaging storm can affect nationwide availability and prices. Early-season extreme weather fluctuations like spring freezes can cause major specialty crop losses. For example in 2012, Michigan farmers lost 90 percent of their tart cherry crop due to a "false spring" event, with unseasonably warm temperatures in March followed by a hard freeze.[561] These events may become more frequent as climate change leads to higher overall climate variability.[562]

Individuals, farming communities, and the entire nation feel the impacts

Collapsing farms ripple throughout the local economy

Farm closures can destabilize rural communities—resulting in job losses, reduced contracting for agriculture-related services, decreased farm input purchases, and less income to circulate within the local economy. For instance, when a dairy farm closes it affects the local tractor dealer, feed suppliers, and the businesses that buy its milk to make dairy products. Surrounding communities depend on reliable agricultural income to bolster their tax bases and maintain a high quality of public services and robust economic growth.[563] As farms go under, farmland is often converted for commercial and residential development, accelerating the loss of other key rural businesses and impacting rural residents.[564]

Facing down an uncertain future

Agriculture work has always been stressful and subject to market- and weather-induced uncertainty, but climate change raises the stakes. The enormous risks related to climate change make the potential for severe losses more likely. Research over the past decade has shown that farmers and ranchers are experiencing more anxiety and mental health issues related to extreme weather events, crop damage, and the well-being of livestock.[565] Today's farmers are asked to produce food, manage the surrounding ecosystems, absorb impacts of trade wars, train the next generation, reduce chemical input use, increase productivity, uphold high standards for animal care, and now address the challenges of climate change.

Growing food insecurity nationally and internationally

Stability in agricultural production and yields ensures a strong, reliable, and affordable food supply. This impacts all consumers, but the challenges of supply shortages and temporary cost increases fall more heavily on those with less discretionary income. In the United States, 11 percent of families faced food insecurity at some point in 2018;[566] robust and resilient agriculture supply chains are critical to keeping prices manageable for American consumers. Climate threats to agriculture will also hinder our ability to influence international food trade and provide humanitarian aid to other countries during times of need. The United States provides about $2.6 billion annually for food assistance (including in-kind and cash aid), and food availability and cost both play key roles in efficiently getting food to those in need.[567] Given the United States' role as a major food exporter and provider of aid, changes in productivity could also undermine our ability to contribute to food security, and with it, regional and global stability.

PROGRESS AND OPPORTUNITIES

Despite the threats, it is possible to adapt to the changing climate while also mitigating future climate risks. Many of the solutions that enhance climate resilience also promote financial resilience. By generating additional revenue streams or making existing operations more profitable, we can strengthen rural economies. For many farmers and ranchers, adaptation may well mean changing certain on-farm practices. For others it might mean changing the type or variety of products they sell. Since the effects of climate change will be regionally specific, adaptation strategies to protect productivity must be tailored to local conditions.

Expanded conservation practices can provide new income

Farmers and ranchers have been sequestering carbon for a long time as part of the practices that keep their soil healthy and productive. Given the beneficial impact these practices provide in the fight against climate change, farmers should be directly compensated for this ecosystem service.

Building soil health and storing more carbon

Farmers and ranchers across the country can help solve the climate crisis by promoting long-term soil health and increasing carbon storage in their soil. Some of the most common and popular practices include planting cover crops, limiting soil disturbance, planting varied crops over time, adopting low- or no-till practices, using perennial species when possible, and planting trees on marginal cropland. For ranchers, managed or rotational grazing, in which livestock graze on a portion of pastureland or rangeland for a limited period of time while giving other parts of the land sufficient time to regrow and recover, has shown potential to increase carbon storage on working lands.[568] The National Academies of Sciences has reported that maximizing carbon storage capacity in lands—in the soils and biomass of grasslands, farms, and forests—is generally the most cost-effective carbon removal technique available today.[569]

© Chesapeake Bay Program

For centuries, farmers have recognized the importance of maintaining soil health. It is a fortunate co-benefit that improving soil health can also mitigate climate change. Many farms are moving in this direction, and various organizations are now offering technical assistance to farmers looking to improve their soil health, optimize carbon storage, and provide marketing tools based on the use of climate-smart or organic agriculture practices.[570,571] Additionally, many food corporations are expanding their greenhouse gas accounting to include decarbonizing their agriculture supply chains by working with farmers and ranchers to lower their carbon footprint.[572]

The livestock industry has received a lot of attention for its emissions, but there are region-specific tools that can substantially reduce these emissions. For example, White Oak Pastures in Georgia is leading the way through a combination of new practices—such as converting marginal cropland to perennial pasture and implementing planned grazing—resulting in a carbon footprint that is 83 percent below conventional farms.[573] Recent research suggests that this type of grazing can also be used in the Upper Midwest to sequester carbon from the atmosphere.[574]

Healthy soil practices can also boost productivity while increasing water storage capacity and reducing flooding and soil erosion associated with intense precipitation.[575] They can also promote crop health and pest resistance; improve nutrient use and water and air quality; and reduce fertilizer use, helping protect neighboring ecosystems and waters from pollution.[576]

For farmers looking to improve their soil health, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service provides technical guidance and tracks success stories across various regions and climates.[577]

"Cattle producers implement personalized conservation practices, including grazing management plans, with technical assistance from USDA and land grant universities. … [The] NRCS' Conservation Technical Assistance (CTA) Program is its most widely used program. The benefit of CTA is its personalized approach: local NRCS employees work with agricultural producers to implement a suite of practices best suited to fit the individual needs of each operation. While funding through EQIP and CSP is important, the foundation of voluntary conservation is CTA. As producers across the country turn to NRCS for conservation practice implementation, on-the-ground technicians are spread increasingly thin.

Previous efforts to consolidate local NRCS and Farm Service Agency (FSA) offices have not increased efficiency, but instead lead to a programming and paperwork bottleneck. In the short term, local staffing shortages and paperwork burdens make it nearly impossible to achieve conservation goals efficiently. In the long term, staff quality decreases and producers become generally disinterested in applying for NRCS programs. We must fix the problem before long term, irreversible damage occurs. Efforts to increase resiliency and efficiency will not be successful unless they are first widely accessible."[611]

— National Cattlemen's Beef Association

Communication to the Special Committee

From growing alfalfa and chili peppers in the desert of Arizona, to producing palm oil in Hawaii, to growing corn and soybeans in the Midwest, soil health has improved the productivity and sustainability of farms across the country.[578]

Existing federal programs administered by the USDA, including the Environmental Quality Incentives Program and the Conservation Stewardship Program, already incentivize some management practices that enhance carbon storage. However, demand for these programs consistently exceeds funding availability, and they do not fully offset the cost of expanding or implementing new activities.

Farmers and ranchers investing in conservation provide a benefit to the public that reaches far beyond their land. Yet, farmers face up front costs of incorporating additional conservation activities in their cropping systems, and these practices also require ongoing investments. We should recognize the value of their contributions by expanding successful agricultural conservation programs and increasing the incentive rate for climate-smart practices to lower the costs—and associated risks—of adopting new approaches. It is critical that farmers have access to resources to offset these capital and operating costs, to reduce the risks in pursuing climate-smart practices, and make sure they have certainty about their farm's future when trying out new approaches.

It is also critical that we recognize the value and costs associated with the long-term, consistent utilization of conservation and soil sequestration practices, and compensate farmers for these costs and this value. Maintaining soil health that is achieved through soil-building practices is particularly important. Soil carbon and the microbiome that secures it underground builds up gradually over time, and stored carbon can quickly be released if soil-building practices are discontinued. Thus, incentives provided to farmers and ranchers for adopting these practices should place a premium on long-term adherence to a consistent soil health protocol. To put it simply: if we want to sequester more carbon on working lands, we need to respect and reward the work it takes to accomplish that goal. We must compensate farmers for their work to sequester carbon, just as we compensate them for the crops they raise.

Technical assistance at the local level must be widely available to assist producers in implementing these practices. The USDA Natural Resources Conservation Service's Conservation Technical Assistance program is critical for landowners across the country, yet its effectiveness has been undermined in recent years by staff reductions, vacant positions, and increasing caseload burdens on employees. The strength of this program lies in its ability to transfer current knowledge and cutting-edge innovation out to farmers as they make decisions about their farming practices. We must restore and expand robust federal funding for Conservation Technical Assistance, so that the bedrock of our working lands conservation approach can continue.

NRCS also has important partners in state agencies, counties, and others who offer practical local expertise and guidance. These other entities are an important part of conservation solutions, but they are not a replacement for NRCS and its Conservation Technical Assistance. One non-federal approach that shows great potential is the use of farming apprenticeships. Apprenticeships have proven a valuable technical assistance tool in addressing existing farming issues, like improving profitability and addressing succession concerns that define the future uses of land. For example, the Dairy Grazing Apprenticeship connects established master dairy graziers with beginning farmers to deliver high-quality, work-based training in managed grazing practices. As new climate-smart practices are developed and tested and new financial incentives emerge, federal investments to expand apprenticeship programs could help beginning farmers get their start and quickly take advantage of the income opportunities from carbon sequestration.

FOOD COMPANIES ARE TAKING ACTION TO REDUCE EMISSIONS ACROSS THEIR SUPPLY CHAINS

Large food companies have recently made significant climate commitments, aiming to reduce emissions not only in their operations but throughout their supply chains.[612] To achieve these goals, these companies are working increasingly closely with their agricultural suppliers to implement sustainable farming practices that decrease emissions and improve crop yields. Companies, including Danone and General Mills, are leading the way by providing funding, incentives, and multi-year cost-plus contracts to suppliers who implement sustainable agriculture practices that improve soil health and store more carbon.[613] General Mills has made the bold commitment to support regenerative agriculture practices on one million acres of farmland by 2030.[614] These types of partnerships help farmers pay the upfront costs of implementing sustainable practices, ensure profitability during the transition, and provide resources and technical assistance along the way. Providing stability and risk-reduction to farmers as they adapt new practices can scale adoption—ultimately increasing long-term profitability, sustainability, and carbon sequestration.

Creating carbon markets

Carbon markets are another option for directly paying farmers and ranchers for the carbon they sequester. Some farmers and ranchers already receive additional income by implementing carbon storage measures and then selling earned carbon offsets to other companies. Through California's cap-and-trade program,[579] livestock producers from any state can now receive carbon offsets by implementing certain practices that reduce greenhouse gas emissions and sell them to California companies in need of offsets.[580] The Regional Greenhouse Gas Initiative (RGGI), a compliance carbon market operating in 10 states in the Northeast and Mid-Atlantic, has deployed a framework to allow farmers, ranchers, and foresters to earn carbon offsets for reforestation activities[581] or through agriculture manure management that captures methane.[582]

In addition to the compliance markets, various voluntary markets are popping up across the nation. Private companies, like Nori and Indigo Ag, and coalitions, including the Ecosystem Services Market Consortium (ESMC), are building voluntary marketplaces to trade carbon offsets for regenerative agriculture practices and actively recruiting farmers to participate.[583]

Still, the lack of a consistent and easy-to-use method for measuring and accounting for the amount of carbon stored in soil is a major challenge for compensating farmers, especially in entirely private and voluntary markets.[584] New tools are available, like the USDA's COMET Farm greenhouse gas accounting system, which allows farmers and ranchers to estimate their current carbon flows, develop and implement practices that can maximize carbon storage, and plan for future climate scenarios.[585] Federal support for research and development that hones methods and easy-to-use tools for measuring stored carbon will broaden the range of farm types that can participate in incentive programs.[586]

Growing the bio-based economy can reduce emissions and bolster rural economies

The United States can create and expand the economic value and market for agricultural products while reducing the use of fossil fuels, because byproducts of agricultural commodities and other natural waste products can be processed into bio-based fuels and chemicals that replace fossil fuel-based products. The growing bio-based products industry contributes $393 billion and 4.2 million jobs to the American economy.[587] These products have helped the United States transition away from foreign fossil fuels, generating a 19-48 percent reduction in emissions when switching from petroleum gasoline to corn-based ethanol for transportation.[588] Many of the bio-based alternatives to fossil fuel-derived chemicals are also less hazardous to human and environmental health; transitioning to them reduces risks to workers, costs associated with handling hazardous chemicals, and long-term contamination passed on to future generations. Additionally, opportunity exists in developing bioproducts that can improve the performance of manmade materials. For example, cellulosic nano-materials derived from woody biomass can be mixed into concrete and other products to add strength and durability.[589] These technologies offer a significant economic opportunity for farmers and managers of working lands, as well as their rural communities.

The federal government has invested in research and development of these products for years, but regulatory uncertainty and market volatility create barriers to private sector investment in advanced biofuels like cellulosic ethanol.[590] Increased federal funding for RD&D of advanced biofuels and bio-based products from waste products and non-food crops could significantly accelerate the adoption of advanced biofuels and bioproducts in American commerce, thereby lowering emissions in the transportation, electric, and industrial sectors.

We need a stable framework that accounts for the climate and ecosystem benefits of these fossil fuel alternatives—and passes this value on to farmers and advanced biofuel producers. This would promote the sustained investment necessary to develop the next generation of these products and accelerate their use by consumers and industry. But as this sector grows, we must focus on increasing productivity on each parcel of land, while protecting high-worth conservation areas.

Updated approaches can reduce emissions from livestock while generating returns

Livestock emit potent greenhouse gases as part of their digestion processes, resulting in the emission of 37 percent of all methane released by human activities.[591] But it is possible to reduce these emissions, improve the efficiency of livestock production, and offer the high-quality products that American farmers and ranchers are known for, and which American consumers demand. We can do this by expanding technologies and compensating farmers and ranchers for emission reductions.

> "On the energy side, biogas systems are unique among renewable energy technologies because we produce energy 24/7 354 days a year with a 95 percent combined efficiency rate producing electricity, heat, and/or renewable natural gas (RNG)."[615]
>
> **—American Biogas Council**
> *Communication to the Special Committee*

Manure digesters capture the emissions from manure and on-farm waste streams and use the resulting methane for fuel—on-farm or sold commercially—or for on-farm electric and temperature control needs. These systems can play a highly effective role in reducing emissions from livestock production.[592] While these technologies have been piloted and deployed in the last two decades, their widespread use has been stymied by technical challenges, shifting regulatory climates that created disincentives for distributed rural electricity generation, and energy prices that did not cover the costs of operation. Most years, farmers make slim profit margins—and in those years, few are able or willing to operate unfamiliar technologies at substantial scale and a financial loss.

For methane digester systems to be financially viable and truly beneficial to reaching climate goals, farmers must be compensated for capturing methane from their herds. This could be achieved by incorporating the added value of the renewable fuel into its price, resulting in additional income and reduced emissions. Additionally, we must make using them less risky, more practical, and increasingly reliable. Biogas companies are actively innovating in how digesters are owned and operated, which may attract farmers who otherwise would not be willing to host a digester on their farm. To take advantage of the emissions capture potential in this technology, financial incentives should be provided to help with the costs of getting a digester up and running smoothly. These upfront costs can be prohibitive to farmers without assistance, but represent relatively modest investments compared to other emissions sequestration strategies.

Beyond simply controlling methane, capturing byproducts of livestock production can create additional sources of income. A digester can be paired with technology to isolate various components of the material it produces, such as bedding and phosphorous that could otherwise contribute to water degradation. Nutrients can be recaptured and recycled for sale as fertilizer or reused onsite, ultimately reducing a farmer's input costs. Additionally, remaining solids can be treated and then reused in applications that require fiber, such as in livestock bedding. To achieve substantial emission reduction from livestock production, these practices, technologies, and management tools need federal investment, prototyping, and incentives. That must be followed by technical assistance that directly serves farmers, including on-farm demonstrations and discussions with Natural Resources Conservation Service and Extension staff.[593,594,595]

Because basic digester systems already exist on many farms, financial incentives should focus on upgrading these systems, retrofitting them to reuse byproducts, and assisting with the installation of new systems. Existing USDA programs can be scaled for this purpose and to meet new demand. The Environmental Quality Incentives Program (EQIP) and the Renewable Energy for America Program provide grants and loan assistance to producers for the installation of digester technology—additional funding for these programs would broaden their impact.[596,597] Investments in these programs are job-creating investments: they create opportunities for construction and engineering experts, as well as for technicians who maintain and troubleshoot the systems. By making these important technologies more affordable, demand for equipment and expertise will increase along with good-paying jobs.

Renewable generation creates additional rural income

More than 130,000 farmers and ranchers have installed some sort of renewable energy generation system on their operation.[598] Many more have deployed energy saving technologies to reduce their energy consumption and costs. Since 2012, the use of wind turbines has increased 56 percent; solar 148 percent; and geoexchange heating 223 percent.[599] Advanced wind systems provide inexpensive, local, and clean power to fuel on-farm operations. They also provide an additional revenue stream through lease arrangements with energy companies, which enter into agreements with landowners for access rights and use of the turbine footprint, while the surrounding land continues to be farmed.[600] Currently, landowners are paid up to $7,000 annually for each wind turbine installed on their land.[601] Other farms host solar arrays, either at grid scale or at a scale that supplements or offsets their use of electricity from the grid. This helps reduce demand

for grid expansion, increases on-farm reliability, and reduces emissions. There is also great potential in transitioning more farm technology and processes to systems fueled with clean electricity or to systems that pair electric power with biofuel-fueled vehicles and machinery. Geoexchange heating and increasing energy efficiency can also reduce the costs of controlling the temperature of large spaces, especially those that house livestock.

During a time of economic uncertainty for many agriculture producers, renewable energy generation can provide consistent income. Farmers and ranchers are using clean energy to their advantage and rural residents are pursuing advancements in energy alternatives that are greener and keep more money in the local economy. Their efforts can be accelerated with financial incentives for clean power generation, assistance with upfront installation costs, tax credits for costs and generation, and policy assistance with the costs and technical barriers of connecting to the grid.[602] Many of these problems would be solved with infrastructure investments that create jobs and upgrade badly outdated rural infrastructure.

Scaling rural broadband increases economic opportunities and climate solutions

An estimated 21 million Americans still lack access to broadband high-speed internet, including 30 percent of rural Americans.[603] Farmers need access to internet at state-of-the-art speeds. Internet access is a basic utility essential for operating in the modern economy. And farmers must have broadband to take advantage of precision agriculture technology and use precise weather forecasting technology in their decision-making, which can help reduce inputs and use of carbon-intensive practices.

Expanding connectivity will improve the quality of life in our rural communities and improve these communities' ability to adapt to a changing climate and emerging agricultural-based business opportunities. It is also crucial for diversifying rural income streams. When people can pursue jobs that allow them to work remotely, rural families have a wider range of economic opportunities to keep them financially solvent. This is crucial for each household's ability to recover from extreme weather events and other crises. It also frees up farmers and rural residents to use extra income to invest back in their farms, test their ideas, pursue education, purchase farm equipment for sustainable practices, and generally take some of the risks related to entrepreneurship.

Many existing and emerging technologies in precision agriculture require high-speed internet access and Global Positioning System connectivity to function. For example, farmers can use these technologies to reduce nitrous oxide emissions by using smaller quantities of fertilizer. Alternatively, technologies used on dairy farms allow farmers to provide specific nutrient rations tailored to each cow and adjusted frequently. This brings down farm costs and reduces quantities of feed that must be grown to raise the animals.

The federal government needs to fund and incentivize the deployment of state-of-the-art rural connectivity so that farmers and rural residents have direct access to the online economy. Once connected, they can take advantage of best available technologies and resources to respond to their increasingly complex management challenges.

Developing new strategies for economic resilience

ECONOMIC DIVERSIFICATION. As extreme weather and a changing climate take their toll on agricultural productivity, increasing the range of farms, crops, and agricultural products produced on one farm or in a region can counteract losses and unpredictable shocks to the system. When production of a certain product is spread among several farms or ranches in different areas, a single catastrophic weather event is less likely to severely restrict the supply of that crop. As weather events that harm crops and livestock become more extreme and less predictable, increasing the agricultural system's resilience to loss will become increasingly essential to the stability of our food supply.

Farmers have also long used diversified income streams to help manage their risk. Dairy farmers make income from their milk, but also from raising and selling corn, soybeans, alfalfa hay, feeder cattle and bull calves. Cranberry growers market for Thanksgiving consumption of fresh fruit, but also press the berries into juice and then dry the remaining berries for a dried fruit snack. Each of these products reaches a different market and spreads out risk. Moving forward, extension agents should focus on providing information to farmers on practices to increase adaptation and overall agricultural diversification.

DIRECT-TO-CONSUMER SALES. In recent years, we have seen a substantial expansion of direct-to-consumer sales. These innovative marketing strategies allow households and restaurants to connect with the farmer raising their food and customize their purchases based on what the farmer is raising. By creating more economic value in these local transactions, local economic resiliency expands and farmland is kept in production rather than being developed. These local food supply chains also reduce the emissions and costs of transporting produce, fresh meat and seafood by air across the country and the world.

While local systems will not replace our commodity-scale crop production, they provide jobs and help consumers develop an appreciation for farming and where our food comes from. As with the tailored technical assistance available to address marketing challenges ranging from building foreign markets to using the USDA Biobased seal, it is important that we continue to invest in this category of agriculture businesses. Expanding existing USDA programs—including the Local Agriculture Market Program, which supports development of infrastructure and systems for smaller, diversified producers—will encourage these connections between resilient farms and ranches and local consumers.

CLIMATE-SMART MARKETING. Marketing can also provide opportunities for increased profits when products are marketed based on special characteristics like origin, growing conditions, or labor standards. For example, the National Organic Standard denotes the use of climate-smart growing and handling techniques, and it has been successful in delivering a higher

income to farmers because of the premium paid for their products. Considering the growing number of consumers who care about climate change, a similar price premium may be available to farmers and ranchers who adopt other climate-smart agriculture practices and through alternate certifications and marketing tools.

Veteran farmers in Virginia who practice rotational grazing

These established and emerging marketing approaches can be advanced through technical assistance programs that meet the specific challenges of that type of agricultural production. For instance, organic farmers have worked to address their unique production challenges through programs including the Organic Research and Extension Initiative (OREI) and the Sustainable Agriculture Research and Education program (SARE). Additional investments in these programs are necessary to help producers address changing growing conditions, respond to new challenges, and share lessons learned.[604]

The increased costs for transitioning a farming system for specialized marketing opportunities can be a challenge for many farmers. Federal support can help address these costs and get the next generation of farmers off to a strong start and encourage greater overall adoption. The National Organic Program at USDA provides a model approach to this in its cost share assistance program for newly organic farmers. Before earning their certification and being able to market their products as organic, aspiring organic farmers must use organic practices, but are not able to benefit from the price premium the seal affords. The cost share program helps them fit organic practices to their operation and manage their increased costs before they can market their products with the seal, and thus access increased margins.[605]

Funding and tools to assist farmers in this transition can make a key difference in supporting beginning farmers, especially when other conventional cost-share incentives are not available.[606] And this approach is cost effective: the one-time cost of organic transition assistance is far less than what many farms receive in conservation payments each year. As new marketing approaches emerge, we should invest in farmers' and ranchers' success by providing a range of climate-smart land management tools that can reduce the financial risks related to adopting new practices, sustain profitability, and achieve long-term carbon sequestration.

BEGINNING FARMERS. Finally, we need to enhance funding for USDA's programs that serve beginning farmers and ranchers with financing and technical assistance. Many beginning farmers start with diversified farms and innovate in the technology and farming practices they use.[607] Supporting this new generation of farmers and ranchers is a strategic and cost-effective way to build on the traditions of the past and broadly deploy new resilient, climate-smart practices.

WILD AND WORKING LANDS

Healthy wild and working landscapes are critical components of the fight against climate change. With the right incentives and policies for land managers, our forests, fields, and coastal ecosystems can reduce carbon pollution, while supporting local economies and outdoor recreation opportunities.

Land management and conservation have enormous implications—both positive and negative—for confronting the climate crisis. Done correctly, our public and private lands can draw significant amounts of carbon dioxide from the atmosphere, bending the warming curve. But without action, our landscapes are increasingly vulnerable to climate change-driven impacts. And as natural and working lands degrade, they can release stored carbon into our atmosphere, creating a continuous feedback loop of increased warming and greater climate impacts.

If we act now, we can deliberately increase the carbon-storage capacity of our forests, fields, wetlands, and coastal habitats. Few climate solutions are cheaper[616] or provide such immediate and visible returns on investment. So it's no surprise these opportunities enjoy broad appeal across the political spectrum. With the right incentives in place, we can reward private landowners who voluntarily adopt climate-smart practices, creating new revenue streams and expanding uptake of these practices.

Protecting and restoring essential landscapes not only avoids carbon emissions, it also ensures precious open spaces are preserved for future generations of Americans. Conservation efforts bolster an outdoor recreation economy that accounts for nearly half a trillion dollars in annual economic activity and millions of jobs.[617] It conserves habitats for game species and expands hunting lands, all while supporting critical ecosystem services like clean water.[618,619,620] Importantly, conservation activities also create jobs, often enabling key demographics, like young people and veterans, to enter or reenter the job market while doing good for their community.

But we are in a race against time. We are already experiencing more frequent dangerous wildfires and severe droughts. Our oceans are warming and becoming more acidic. Treasured natural icons—the glaciers of Glacier National Park,[621] the crystal blue waters of Lake Tahoe,[622] the Everglades' sea of grass[623]—are already diminished and face growing threats. Across the country, climate stressors undermine the productivity of our fisheries and working lands, and the well-being of the communities and economies that rely on them. Often, once these valuable natural resources are gone, they are lost for forever. The stakes could not be higher, nor the potential outcomes more stark.

The right mix of conservation incentives and tailored policies to promote good management practices can ensure the scales tip towards a sustainable future. But we must ensure conservation efforts are collaborative, aligned with local priorities and values, and developed in close coordination with stakeholders on the ground.

Congress must play an essential role in scaling conservation and climate-smart management efforts by:

> "Having spent my lifetime exploring mountain environments, I have witnessed the impacts of climate change firsthand. It is clear to me our winters are warming and our snowpack is diminishing. As an alpinist, I climb a great deal of glaciers and ice, and there is no doubt increased temperatures are melting away both my sport and my livelihood."[721]
>
> **— Caroline Gleich**
> *Professional ski mountaineer*

- ✔ Providing financial incentives for targeted management practices that naturally capture and store carbon, which can create new income streams for working lands.
- ✔ Supporting technical assistance and outreach to land managers on carbon management and climate adaptation, with a focus on producers with limited resources and historically underserved communities.
- ✔ Increasing funding for programs that support conservation and protect coastal wetlands, open space, and forestlands from conversion and development.
- ✔ Providing additional support for programs that mitigate the risk of catastrophic wildfires, enhance drought resilience, and address invasive species and pests.
- ✔ Creating a Civilian Conservation Corps.
- ✔ Funding more research on effective land-based carbon sequestration opportunities and monitoring practices.

We currently have a choice to act to make our wild and working lands a net sink for carbon. But that choice may not be available to us much longer, underscoring the need for quick action and increased investments. In return, we will reward land managers, safeguard our most cherished and culturally significant landscapes, grow local economies, and create jobs.

RISKS OF INACTION

Climate change is already harming our natural resources

Climate change is already harming forests, rangelands, deserts, and coasts across the United States, compromising the many benefits these natural resources and ecosystems provide us—like food, water, flood mitigation, and storm protection. Climate impacts are damaging America's natural heritage and the vibrant outdoor recreation economy that supports communities across the country. Unfortunately, impacts to these landscapes will further exacerbate climate change by lessening natural capabilities to store carbon, and in some cases becoming a net source of carbon pollution.

WATER QUALITY. A clean water supply is essential for healthy communities and ecosystems. Climate change compromises water quality by raising water temperatures and increasing intense downpours, which mobilize sediment, nutrients, and toxins into nearby waterbodies.[624] These changes contribute to the development of harmful algal blooms,[625] which are linked to cascading effects throughout an ecosystem, like die-offs of species higher in the food chain.[626] These events also harm local and regional tourism, evident in the Gulf of Mexico beach closures triggered by increasingly frequent harmful algal blooms.[627] Algal blooms can also compromise local water supplies. In 2014, half a million people in Toledo, Ohio, were warned to avoid drinking local water supplies when a treatment plant was overwhelmed by toxins from a harmful bloom in Lake Erie.[628] In 2018, Salem, Oregon, issued a drinking water advisory for vulnerable populations in response to a harmful bloom in a lake upstream from the city's drinking water source.[629] Clean water is a human right, and a compromised water supply is both a public health crisis and an environmental injustice that worsens existing inequities.

DROUGHT. Climate-driven droughts are intensifying.[630] Snowpack is critical for storing winter precipitation for use throughout the spring and summer. However, less precipitation is falling as snow, and snow is melting earlier, leading to less water availability later in the year.[631] A recent study identified the Colorado, San Joaquin, and Columbia River Basins as regions that face particularly significant challenges as climate change leads to diminished snowpack.[632] The Colorado River alone provides municipal water to nearly 40 million people, supplies water to irrigate nearly 5.5 million acres, and is a critical resource for at least 22 federally recognized Tribes.[633]

In the Southwest, climate change contributed to making 2000 to 2018 the driest 19-year span since the late 1500s and the second driest since the ninth century—leading to heightened wildfire risk and increased water supply challenges.[634] In 2015, extreme drought conditions in Puerto Rico and the U.S. Virgin Islands led to weeks of water rationing that affected millions of people.[635] This summer, another severe drought in Puerto Rico has triggered water rationing for nearly 140,000 homes and businesses, in

the midst of the COVID-19 health crisis.[636] The increasing frequency of drought will necessitate difficult tradeoffs in communities forced to allocate limited water supplies among competing demands.

Droughts also leave forested landscapes more susceptible to wildfires, invasive species, and beetle outbreaks.[637] On rangelands, they can threaten the survival of some carbon-storing perennial plants,[638] and dramatically compromise productivity and economic viability for farmers and ranchers.[639] In 2013, after an extended drought across the Great Plains and western United States, the domestic cattle crop was the smallest since 1951.[640] From 2012 to 2016, a severe drought across portions of the West caused billions of dollars in economic losses and killed thousands of trees.[641]

WILDFIRES. Large, deadly, and uncharacteristic wildfires are becoming increasingly frequent due to climate change-driven trends, including drought, increasing air temperature, and earlier snowmelt.[642,643] Expanding development in the wildland-urban interface, as well as increased fuel loads due to decades of fire exclusion, mean these fires cause more harm. The duration of wildfire season and the cost of fire management have increased over time, and if we do not act, we will need to spend billions more dollars.[644]

Extreme wildfires are clearly serious dangers to communities in their path, but they can also be devastating for ecosystem health. Fire has always had a natural and beneficial role in certain ecosystems. Yet climate change is increasing the frequency of uncharacteristic and extremely high-intensity wildfires that damage, rather than enhance, the resilience of the burned landscape. Such fires physically alter the ecosystem and burn stored soil carbon back into the atmosphere. They also have long-term negative effects on a range of processes, like soil productivity, soil water infiltration, nutrient retention, and resilience against invasive species.[645] In the Intermountain West, for example, frequent wildfires have facilitated the spread of invasive cheatgrass, a highly flammable annual grass that further fuels wildfire risk.[646]

Water infrastructure and downstream water supplies are also at risk from more frequent and intense wildfires. For example, catastrophic fires in 2012 severely degraded substantial portions of the Fort Collins and Greeley watersheds in northern Colorado. Subsequent rainfalls on the burn areas triggered heavy runoff into a major water source. As a result, the cities had to find alternative water supplies and apply costly methods of water treatment for months.[647]

"Landowners are already seeing an increase in the frequency and severity of weather extremes across the country. Members of NACD's Soil Health Champions Network report that they have seen prolonged droughts, more intense winds, extreme heat and heavy rains at inopportune times. They also note the weather has been less dependable than it once was."[722]

— National Association of Conservation Districts
Communication to the Special Committee

Cheatgrass-dominated weed patch after wildfire

Hanauma Bay, Hawaii

OCEAN ACIDIFICATION AND WARMING. Climate change is disrupting ocean ecosystems, with effects worsening as greenhouse gas levels rise. Increasing atmospheric carbon dioxide levels are leading to the uptake and absorption of higher levels of carbon dioxide in the ocean, such that surface ocean waters have become 30 percent more acidic since the preindustrial period.[648] This ocean acidification disrupts the lifecycle of calcifying species like clams and oysters,[649] potentially jeopardizing thousands of fishing jobs and hundreds of millions of dollars in revenue.

Global warming is similarly increasing ocean warming, which can lead to lower oxygen levels, expanded dead zones, and changes in abundance of marine animals and plants.[650] Related changes in the timing, distribution, and productivity of fisheries bring social and economic stress to communities that rely on fishing for food and income.[651] Shifts in the location of fisheries, such as the movement of sea bass and cod stocks northward, can lead to management conflicts if the shift crosses international boundaries.[652] One recent ocean heat wave in the north Pacific, dubbed "the blob," was associated with a 70 percent drop in the Pacific cod fishery—worth $100 million annually—and massive die-offs of whales and seabirds.[653]

Coral reefs are particularly sensitive to changes in temperature and acidity.[654] Live coral cover globally has decreased from a historical baseline of 50-75 percent to only 15-20 percent.[655] Under worst-case scenario models, nearly all U.S. coral reef coverage will disappear by 2100.[656] Climate-driven coral bleaching and a decline in reef cover will diminish the wide range of benefits they provide coastal communities, including storm surge protection, tourism economies, and habitat needed for commercial and recreational fishing.[657]

SEA-LEVEL RISE. Sea-levels are rising, threatening coastal communities and flooding and eroding marshes, mangroves, and beaches.[658] These harmful effects can be amplified when natural or artificial barriers block inland migration of threatened ecosystems, known as "coastal squeeze."[659] In eastern Maryland, Blackwater National Wildlife Refuge is increasingly transitioning from wetland to open water.[660] This refuge, sometimes called the Everglades of the North, is a vital stop for migrating birds on the Atlantic Flyway.[661] Adjacent agricultural communities are similarly grappling with expanding salt water intrusion.[662]

The low-lying Midway Atoll, part of the Papahānaumokuākea Marine National Monument that encompasses the Northwestern Hawaiian Islands, provides nesting grounds for nearly 75 percent of the global breeding population of Laysan albatrosses and 36 percent of black-footed albatrosses.[663] Projected impacts from sea-level rise and extreme weather show that 60 percent of albatross nests could be lost during future high-water events.[664] The loss of important nesting sites could affect the overall population and conservation status of these breeding birds.

DIMINISHED CARBON SEQUESTRATION. Climate change will disrupt multiple natural sources of carbon storage, potentially tipping the scales in the fight to reduce emissions. Coastal ecosystems like mangrove forests and salt marshes are highly efficient at sequestering carbon, but sea-level rise can impair that attribute.[665] Additionally, as the ocean warms and stratifies, less carbon is transported to the deeper ocean and ocean floor,[666] decreasing the ocean's historical significance as a carbon sink. Climate effects on forest carbon sequestration will vary depending on forest type and regional circumstances,[667] but emissions from forests may increase substantially where climate change induces more severe wildfire. For example, one analysis estimates that 160 million metric tons of carbon were released as a result of the severe 2015 Alaska fire season.[668]

Potentially most alarming, record warming in the Arctic is compromising permafrost carbon storage.[669] Permafrost thawing can significantly accelerate climate change[670] because this ecosystem is estimated to store more carbon than has been released via fossil fuel combustion to date.[671] The Arctic is already warming twice as fast as the rest of the planet, but additional increases could create a tipping point: an irreversible cycle of warming, leading to carbon and methane releases, leading to additional warming.

"Healthy forests and healthy grasslands are true carbon sinks, providing for carbon sequestration while providing key habitat for multitudes of species that exist alongside human uses of the landscape."[723]

— National Cattlemen's Beef Association

Communication to the Special Committee

Climate change is threatening species and biodiversity

Scientists have concluded that we are currently experiencing the sixth mass extinction event in the history of the earth.[672] This is a result of numerous human-driven factors, but climate change is exacerbating the problem. In fact, one study predicts that if emissions continue unabated, an additional 16 percent of species will be threatened with extinction due to climate change by the end of the century.[673]

Populations of wild rice in the Upper Midwest are declining due in part to higher temperatures, decreasing ice cover, and increasing extreme precipitation events.[674] These changes threaten a vital part of the culture and economy of the Ojibwe of Michigan, Minnesota, and Wisconsin—illustrating how climate change can reverberate throughout communities that depend on affected resources.

Bee populations are already in dramatic decline throughout the world—and now climate change is creating new threats to bees and other pollinators.[675] In locations where plants flower earlier due to warmer weather, their dominant pollinator may not keep pace by hatching earlier. This mismatch harms the plant and the pollinator[676] and creates cascading impacts that might ultimately threaten the health of our food system.

Furthermore, invasive species already cost the United States more than $120 billion in damages every year, a number that is likely to increase as temperatures rise. By nature, invasive species are typically able to adapt quickly to new and unusual environments, which makes them better suited to a changing climate than native species.[677] When invading species out-compete and crowd out native species, it drives ecosystem degradation. For example, purple loosestrife, an invasive weed, is able to shift its life cycle in response to climate cues.[678] As it crowds out native plants, it reduces food, shelter, and nesting sites for waterfowl, turtles, frogs, and other wildlife, and ultimately reduces hunting, fishing, and boating opportunities.[679]

Climate change will impact treasured and economically important landscapes

AMERICA'S NATURAL HERITAGE. Iconic American landscapes, including national parks, national wildlife refuges, and Forest Service and Bureau of Land Management lands, are important parts of America's heritage. They are also major tourism drivers for surrounding communities. In 2019, the National Park System alone received nearly 330 million visitors[680] and contributed $40 billion to the U.S. economy.[681]

Rocky Mountains, Colorado

These special places are already facing irrevocable alterations from climate change. The majority of national parks are on the warmest end of their historical temperature patterns.[682] Sea-level rise threatens the unique ecosystem in Everglades National Park, a massive freshwater wetland.[683] Warming in Lake Tahoe is increasing algal growth, setting back long-standing efforts to preserve this beautiful but vulnerable high-altitude lake.[684] In and around Colorado's Rocky Mountain National Park, warming temperatures have helped spur a beetle infestation that led to widespread tree death over more than 350,000 acres.[685] Rapid warming is also melting the namesake glaciers of Glacier National Park. When founded in 1910, the park had over 100 glaciers; today, only a few dozen still meet the size criteria to be classified glaciers—and those, too, are melting.[686] In the Arctic National Wildlife Refuge, climate change is diminishing the wintertime habitat of the refuge's iconic caribou herds, threatening an important subsistence hunting resource for Alaska Natives.[687] Shorter winters and warmer temperatures are dramatically changing Yellowstone National Park, where invasive species are spreading and wildfire risk is increasing.[688] One Yellowstone researcher reflected, "By the time my daughter is an old woman, the climate will be as different for her as the last ice age seems to us."[689]

OUTDOOR RECREATION ECONOMY. Tourism associated with outdoor recreation is an irreplaceable economic foundation for communities across the country. The outdoor recreation industry annually accounts for $427 billion in consumer spending,[690] supports 4.5 million U.S. jobs,[691] and generates an estimated $125 billion in federal, state, and local tax revenue.[692] The sector is a major economic contributor in every state, particularly benefitting towns near national parks, public lands, and adventure destinations.[693]

The U.S. snow sports industry—which alone generates $73 billion annually and supports 695,000 jobs[694]—is already facing shortening winter recreation seasons.[695] In testimony before the Special Committee, entrepreneur and snowboarding pioneer Jeremy Jones described his business as "one of the many small businesses in mountain towns that depend on a stable climate and snowy winters," and noted that "[w]ith every inconsistent winter, my community's economy suffers. Snow is our currency."[696] Nearly all U.S. winter recreation areas are projected to see season length shrink, some as much as 50 percent by 2050 and 80 percent by 2090.[697] These changes are not merely economically damaging. Hall of Fame NHL goaltender, Mike Richter, testified before the Special Committee: "As enjoyable as the simple act of skating is—its efficiency, rhythm, and speed—to skate outside is altogether different. It is pure magic. [...] When I see a pond melt, I know the lost opportunity for this generation to experience the joy of this wonderful game. What we all need to understand is that this represents something far more ominous."[698]

Also at risk is wildlife-dependent recreation, including hunting, fishing, and birding[699]—responsible for over $150 billion dollars of expenditures in 2016 alone.[700] Climate change is already harming native trout populations that depend on cool stream temperatures. Projections indicate that climate change could annually cost as much as $6.4 billion in value lost just from freshwater recreational fishing.[701] Important game species are also at risk, like the ruffed grouse, which is adapted to living in regions where snow typically covers the ground in winter months. Grouse habitat is expected to shift northward in a warming climate, such that Pennsylvania may no longer be able to host its own state bird.[702] Many of these species, including elk, pronghorn, pheasant, waterfowl, and deer, are critical drivers of economic activity in small towns and rural areas across the country.

PROGRESS AND OPPORTUNITIES

Our natural resources are part of the solution to climate change

U.S. lands currently sequester much more carbon than they emit, providing a net "carbon sink." In 2018, U.S. lands sequestered a net 800 million metric tons of carbon dioxide equivalent, offsetting 12 percent of economy-wide greenhouse gas emissions.[703]

We must seize the opportunity to make conservation and land management a core climate, jobs, and economic strategy.[704] Providing incentives and support for stewardship can help ensure private and public lands continue to lead the way in mitigating climate change while providing essential ecosystem services.[705] Additionally, rewarding practices that naturally capture and store carbon can help bolster the economic viability of working lands.

Promoting climate-smart management

Management practices that enhance the carbon sequestration potential of an existing landscape can take a variety of forms, depending on regional characteristics. Forest management and restoration techniques that increase soil carbon and tree biomass can increase overall carbon sequestration.[706] Adopting certain reduced tillage, grazing, and cover crop practices can enhance sequestration in cropland and pasture.[707]

For private landowners, financial incentives can help encourage the use of enhanced carbon sequestration practices. Many are already applying soil health and other sequestration-enhancing practices because it can increase their resilience and improve their bottom line. Financial incentives can help make the difference for landowners who are interested, but have limited resources to switch practices.

A wide range of options are emerging that could help provide this kind of support, including tax credits, Farm Bill financial incentives, payments via carbon markets, and others. But we must do more to develop and scale up these opportunities, while ensuring they are both rigorous and accessible to landowners. In particular, ambitious climate policy that provides long-term, substantial financial support for such measures will help land managers seize the opportunity presented by this low-cost climate solution.

Technical assistance and outreach to landowners is also an important component to help landowners scale the design and implementation of carbon management and climate adaptation practices. A wide range of actors can help facilitate this type of technical assistance, including USDA field offices, the Department of the Interior, state agencies, land grant universities, and private organizations. However, the federal government needs additional capacity and funding, and programs should be developed with a particular focus on producers at the beginning of their careers, historically underserved populations, and producers with limited resources.

For public lands, widespread implementation of targeted management practices will depend on further investment and strategic planning in the agencies charged with managing those lands. For example, to harness carbon sequestration opportunities and optimization in our national forests, agencies will need adequate resources to conduct research, implement management strategies based on the best available science, tailor plans to fit specific forests types, and work in collaboration with stakeholders. It is crucial that management strategies reflect local circumstances and are developed in partnership with landowners, state, local, and Tribal officials, and other key stakeholders.

Protecting critical ecosystems

Natural carbon sinks can release significant quantities of stored carbon if the landscape is converted to another use—for example, if forests are converted for commercial development. Rewarding and supporting conservation and responsible management of at-risk, high-sequestration lands helps keep carbon stored in these landscapes.[708] These efforts can also support ecosystem services, maintain wildlife habitat, and strengthen resilience against future climate impacts.

Protecting coastal wetlands and mangroves from development for housing, infrastructure, or other uses must be a priority, because coastal wetland ecosystems can release large amounts of carbon when disturbed.[709] Reducing disturbance of seagrass beds is another opportunity to protect so-called "blue carbon."[710] Experts believe blue carbon could be a key climate solution, offering carbon storage capacity of over 2.8 Gt of carbon dioxide by 2060 if implemented widely in the United States.[711] Congress should support and expand the available incentives and funding opportunities to actively manage and restore coastal wetlands. Local governments can make good use of federal funding to improve coastal carbon storage, while also achieving the environmental benefits of natural shorelines that provide natural protection from storms, sea-level rise, and coastal water contamination. In the future, land managers may also be able to implement blue carbon projects to earn carbon offsets and diversify their revenue streams.[712]

On land, forests account for the substantial majority of the U.S. carbon sink.[713] But every year, over a million acres of forestland are developed.[714] Maintaining forestland and avoiding land conversion can help continue storage of carbon in a forest's trees, plant matter, and soils.[715] For example, in the Pacific Northwest, stands of old growth forests that have been undisturbed for over a hundred years contribute substantially to carbon sequestration.[716] Conservation of grasslands and wetlands can similarly protect carbon sequestration stores, while also preserving valuable habitat for ducks, grassland birds, and other game.[717]

The good news is that Congress recently passed historic legislation, the Great American Outdoors Act, which fully and permanently funds the Land and Water Conservation Fund (LWCF) to protect our public lands and invest in state and local projects. This broadly popular, bipartisan policy will create jobs and grow our economy while protecting nature and important carbon sinks. But to meet the scale of the challenge—and the opportunity—we must do much more.

Existing initiatives, like the Land and Water Conservation Fund, Forest Legacy Program, North American Wetlands Conservation Fund, WaterSMART, and USDA conservation programs, must be expanded and must prioritize financial investments in projects that protect natural landscapes critical for carbon sequestration and climate resilience. Habitat Conservation Plans, Candidate Conservation Agreements, and Safe Harbor Agreements are all existing tools that can help further incentivize conservation on private lands, provided the government funds them adequately.

Increasing conservation of landscapes at risk of disturbance helps ensure future generations have an opportunity to enjoy these natural spaces. These efforts can also support the growing outdoor recreation economy—for instance, by benefiting habitat for game species and increasing hunting lands. Where possible, conservation efforts should also improve access to public lands and the great outdoors for all Americans, particularly low-income communities and communities of color. Protecting parks and open spaces in accessible locations near communities can help ensure that everyone is able to share and enjoy our nation's natural treasures.

Managing and adapting to the effects of climate change

Managing the increasing risk of extreme wildfires is another key component of enhancing natural carbon sinks. Emissions from catastrophic wildfires can negate greenhouse gas reductions elsewhere. To combat this, we need substantial investments in fire mitigation and forest restoration. Such efforts must support regrowth and restoration of native habitat, be based on the best available science, reduce the spread of invasive species after fires, and improve forest and watershed health. Furthermore, increasing the capacity of wildland firefighting resources can reduce the risk of catastrophic fires. Effective fire mitigation will also depend on robust partnerships among federal, state, Tribal, and local entities.

Beyond its effects on wildfire risk, climate change diminishes the value of ecosystems for storm protection, habitat connectivity, and water storage and filtration. The loss and degradation of essential ecosystem services is yet another cost of inaction on climate change. Policy needs to evolve to better support land managers' ability to adapt to these changes. For example, private and public land managers will face increasingly frequent and severe drought, particularly in the West.[718] Greater support for programs to enhance drought resilience—for example, through improved snowpack monitoring or removal of invasive species that consume significant quantities of water—will help avoid dramatic declines in local landscape and economic health.[719]

PUBLIC-PRIVATE PARTNERSHIPS IN WILDFIRE MANAGEMENT

According to the Congressional Research Service (CRS), an average of more than 71,000 wildfires have burned roughly 6.9 million acres across the country annually since 2000—more than double the average annual acreage burned in the 1990s.[724] The same CRS report indicated that last year, 65 percent of the acreage burned by wildfires was on federal lands. In the West, where there is a checkerboard of public and private land, wildfire mitigation and management requires cross-coordination among federal agencies, state agencies, Tribal communities, local municipalities, and private landowners.

In an effort to help improve the efficient use of resources, many fire-prone western states are working to improve coordination and communication among local, state, and federal wildfire teams. For instance, in 2019, the governor of Nevada, U.S. Forest Service, Bureau of Land Management (BLM), and U.S. Fish and Wildlife Service (USFWS) finalized a Shared Stewardship Agreement to better identify projects that would help reduce wildfire risk and increase the number of acres treated on state, county, private, Tribal, or federally managed lands.[725] The Agreement, which was the first of its kind to include the BLM and the USFWS,[726] acknowledges the many threats facing Nevada's ecosystem, declaring that, "[l]arge-scale wildland fires are one of the greatest threats to Nevada's landscape and are occurring with increasing size, severity and frequency."[727] These catastrophic fires, fueled by our changing climate, require strong interagency partnerships for effective wildfire mitigation.

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Creating jobs through a Civilian Conservation Corps

Achieving the goals outlined above will take time and effort on the ground. Amidst record unemployment, investing in our land, water, and wildlife is an opportunity to create good-paying jobs in the outdoors while addressing climate change. Established by President Roosevelt during the Great Depression, the original Civilian Conservation Corps helped build infrastructure across our public lands. These investments ultimately laid much of the foundation for our outdoor recreation economy while creating jobs and providing skill-building opportunities for youth, veterans, and many others.

A new, federally funded Civilian Conservation Corps should scale up existing efforts and focus on projects that enhance natural carbon storage, address the effects of climate change, and build resilient infrastructure. Putting people to work on conservation solutions will help tackle the climate challenge while building skills and creating economic opportunity in communities across the country.

Supporting needed research

In order to develop effective natural solutions to address climate change, the federal government should increase funding for research and monitoring related to carbon sequestration practices. Congress should fund additional research on effective land management practices; watershed and forest health; and carbon sequestration measurement and verification techniques. Particularly to support blue carbon efforts, Congress should fund research to determine the fate of organic carbon in coastal ecosystems, develop best management practices to store more carbon, and study the feasibility of improving storage capacity by adding carbon-rich materials to these ecosystems.[720] Research priorities should also support climate adaptation—like improving monitoring of key indicators like fisheries data, or researching how to neutralize pests or invasive species—to ensure the resilience of our natural resources in a changing climate.

Native and Tribal Priorities

American Indian, Alaska Native, and Native Hawaiian communities are some of the most climate-exposed in the United States. Climate-induced disruptions to weather patterns and natural landscapes are not only environmental and economic pressures for Native peoples; in many cases they also undermine core social identity and threaten cultural survival.[728]

Climate impacts disproportionately interfere with subsistence practices like agriculture, hunting, and fishing. The reduced availability of stable food sources poses a threat to immediate health and well-being for many Native peoples, in addition to jeopardizing vital cultural traditions. Furthermore, Native communities are often uniquely place-based, with histories that tie them intimately to their ancestral lands.[729] With some Native coastal populations across the country already considering or actively pursuing community relocation in the face of climate impacts, cultural continuity is also under threat.[730]

In addition, revenue and jobs from fossil fuel development can be an important part of some Tribes' economic security. It is essential to work with Tribes to develop new opportunities and long-term economic solutions for communities impacted by decarbonization.

As Congress responds to the climate crisis, it must not repeat the underinvestment and neglect that has too often defined our government's relationship with Native peoples.[731] A painful legacy of colonization and forced assimilation will pervade any federal efforts to address climate impacts on Native communities and ways of life, particularly when those efforts necessitate community resettlement.[732] It is therefore essential that any decisions affecting Native resources, lands, and livelihoods be reached in full partnership with Native peoples from the outset.

The Special Committee partnered with the Senate Committee on Indian Affairs to solicit feedback from American Indian, Alaska Native, and Native Hawaiian leaders on how to best assist their communities with climate mitigation and resilience efforts. Below is a summary of some of the most popular suggestions from the responses the committees received.

Native and Tribal communities' input to the Special Committee

- **Improved Native consultation in federal decision-making, and localized climate science to meet the needs of communities.** Congress should consider establishing a formal Native-federal task force on the climate crisis.

- **Funding for the Bureau of Indian Affairs' (BIA) Tribal Climate Resilience Program.** Over the past few years, BIA has only been able to fund 30-50 percent of Tribal resilience funding requests.[733] Respondents overwhelmingly cited it as the most helpful federal program for identifying climate threats and developing plans in response. Congress must reauthorize the program and provide robust funding.

- **Improvements to the Environmental Protection Agency's (EPA) Indian General Assistance Program (IGAP).** Respondents credited IGAP as one of their most consistent funding sources for environmental work like solid waste management and air quality, but asked for more flexibility to address climate change impacts directly.

- **Waive fund-matching requirements for federal climate programs.** Even low matching requirements are a barrier for Native communities that are impoverished and rural.

- **End the competitive grant model for climate programs.** Competitive grants pit Tribal governments and Native people against each other and make it hard for communities to get funding if they do not have some level of capacity already developed.

- **Offer more Federal Emergency Management Agency (FEMA) technical assistance.** This should include an emphasis on improved hazard mitigation and incident command training.

- **Provide long-term sustainable funding through FEMA and the Department of Housing and Urban Development (HUD) to address displacement and relocation from sea-level rise and other climate impacts.** Funding could address issues like housing relocation assistance and floodplain relocation. Respondents also suggested a new National Oceanic and Atmospheric Administration (NOAA) annual grant program to assist with community relocation.

- **Create a Climate Migration Task Force.** The task force would establish both a legal and financial mechanism and institutional governance framework for resettlement.

- **Amend laws like the Federal Power Act to promote Tribal self-governance, self-determination, and sovereignty.** This would make Tribal authorities comparable to state authorities under federal law—over issues like water quality, environmental protection, and clean energy production.

- **Provide assistance to facilitate the transition from fossil fuels to clean energy, including interest-free loans and other financing programs for clean energy projects.** Support for small-scale renewable energy projects will be crucial. Some respondents noted existing programs at the Department of Energy's (DOE) Office of Indian Energy that help with energy transitions; other highlighted the need for research on the viability of available renewable technologies in Arctic conditions. The Government Accountability Office (GAO) also found that Tribes' limited access to capital and commercial energy markets has hindered Indian energy development. This is a barrier to making clean energy development on Tribal lands profitable and sustainable.[734]

- **Enable forest carbon capture, conversion of marginal lands to prairie lands, regenerative agriculture, and other land management practices.** Some respondents noted BIA's efforts to draft a carbon policy, which have been ongoing since 2003.

- **Develop and pass equitable legislation related to carbon pricing or cap-and-trade.** Such legislation should include a specific set-aside of revenues for Native communities, among other considerations.

- **Build capacity within communities to monitor and measure changes they are seeing.** For instance, training local people to carry out their own long-term flooding and erosion monitoring would build a sense of empowerment, and could create permanent local jobs with federal support.

- **Develop a single resource registry to document all ongoing Tribal climate mitigation initiatives.** Such a catalogue would be accessible to all Native communities.

- **Support and utilize traditional ecological knowledge.** The utilization of traditional ecological knowledge—an accumulation of centuries of knowledge, practice, and beliefs that has been passed down to Native communities for generations—is a valuable tool for Native communities to tailor climate change responses to their needs.

The Nez Perce Tribe emphasized: "there are no technological or economic barriers to solving the problem" of climate change; rather, "it is a lack of societal and political will to take the action needed at the scale necessary to solve this problem."[735] Native peoples must be active partners in our efforts to address the climate crisis. Congress should give Native communities the autonomy and resources to deploy innovative climate solutions at the local level. In return, federal policymakers would benefit from the wealth of traditional knowledge and Tribal practices these communities can bring to the table as we formulate our collective response.

HEALTH AND HEALTH CARE

> Climate action can prove to be one of the greatest health opportunities of the century. Reducing emissions will save hundreds of thousands of lives, avoid billions of dollars in health care costs, and reduce health inequities that have for too long afflicted specific communities.

Climate change constitutes the "greatest public health challenge of the 21st century," according to more than 70 medical organizations.[736] But tackling the climate crisis and its related inequities could also prove the greatest health opportunity of the century. If we move quickly to mitigate and adapt to climate change across our economy—from transportation and electricity, to industry and agriculture—we will immediately save lives and make Americans healthier.[737] Public health workers, doctors, and nurses can be powerful partners as we respond to and prepare for the health impacts of climate change.[738]

Medical experts are warning with increasing urgency that climate change is a human health disaster. Vector-borne illnesses, like Lyme disease, West Nile Virus, and malaria, are spreading to new areas as the planet warms and ecosystems change. Extreme heat is making outdoor work increasingly dangerous, and climate-induced disasters are becoming more common and destructive.[739] The injuries and loss of life from such events are quantifiable and devastating. Other impacts are harder to measure but no less harmful, such as the trauma of losing your home and social support system to storm damage or community relocation, or the stress, anxiety, and depression of knowing that the next disaster could be around the corner.[740]

Climate change also puts our health care infrastructure at risk. The COVID-19 pandemic has exposed major weaknesses in our hospitals and health care systems. It has also demonstrated how our failure to reduce harmful air pollution has worsened the effects of the virus, which can exacerbate dangerous respiratory diseases.[741] If the United States fails to act now, the climate crisis will contribute to—and severely complicate—future public health emergencies.

By eliminating carbon emissions and other pollution, we can reduce the likelihood of future climate threats, while providing immediate protections to the populations most at risk from the climate crisis: children, the elderly, pregnant people, people with chronic illnesses, people with disabilities, and low-income communities.[742] We can enhance community safety and resilience and improve our nation's overall health.[743]

We also have a chance to confront a legacy of environmental injustice in frontline communities throughout our country. These areas are disproportionately exposed to extreme events—the neighborhoods "hit first and worst by climate impacts," as environmental justice leader Michele Roberts told the Special Committee.[744] And for decades, racial and economic inequalities have also concentrated sources of harmful pollution in low-income areas, communities of color, and Native communities.[745] The fossil fuel combustion at these sites not only contributes to the greenhouse gas emissions that cause climate change, it also contributes to air pollution, which exacerbates other illnesses and is increasingly linked to premature death.

The United States' efforts to combat climate change and adapt to its impacts will create health, equity, and economic benefits. Federal policies to achieve climate-related health benefits should include:

- ✔ Strengthening and enforcing emissions standards for vehicles, power plants, and other pollution sources.
- ✔ Creating standards and incentives for health care facilities to reduce greenhouse gas emissions.
- ✔ Funding programs that provide essential health services like vaccination, child health, and maternal health, and access to safe food, clean water, and sanitation.
- ✔ Implementing early warning systems to notify residents about emerging threats or climate-fueled disasters.
- ✔ Requiring health care facilities to prepare for extreme events and enabling hospitals and other health facilities to be epicenters of community resilience.
- ✔ Providing technical assistance and financial support to help health care professionals, first responders, and communities develop climate preparedness and response plans.
- ✔ Supporting city, Tribal, and state infrastructure that reinforces health, such as low-cost public transit, more green space, and energy-efficient buildings.

By reducing pollution, investing in preparedness, and tracking and warning about emerging health impacts, the United States can improve public health while combatting climate change. Climate-sensitive extreme events can results in billions in health care costs,[746] yet these numbers do not represent the cost of increasing chronic illnesses or new diseases brought about by a changing climate. By choosing climate action, the United States can avoid these escalating health care costs and save American lives.

RISKS OF INACTION

Climate change affects the health of all U.S. residents

Climate change is linked to poor air quality; increased heat exposure; more frequent and severe floods, droughts, and other extreme weather events; the spread of vector-borne diseases; impaired access to safe food and water; and stresses to mental health—all of which contribute to a growing public health crisis. These various climate impacts aggravate existing health problems like asthma, lung disease, heart disease, and diabetes, driving up health care spending and fatalities.[747] For example, extreme heat is associated with an increased risk of heart attack,[748,749] and numerous studies of temperature-related morbidity report increases of cardiovascular and respiratory adverse events with increased heat.[750,751] A case study of ten major climate-sensitive events in 2012 found that health care costs exceeded $10 billion, and these costs will grow as climate change impacts get worse.[752]

AIR QUALITY. Climate change contributes to heat waves, wildfires, and longer pollen seasons, all of which lower air quality. Climate change increases the frequency and severity of heat waves,[753] which are linked to declines in air quality that can trigger health problems for those with respiratory issues. With increased temperatures, pollutants emitted from industrial processes and fossil fuel combustion, such as nitrogen oxides and volatile organic compounds, more quickly react to form ground-level ozone.[754] Ground-level ozone pollution harms the lungs and is linked to asthma, diminished lung function, and premature death.[755,756] Bigger and more frequent wildfires can also increase smoke exposure and particulate matter air pollution that can damage the lungs and increase hospitalizations due to respiratory and cardiovascular problems.[757,758,759] Longer warm seasons will lead to higher pollen concentrations, increasing asthma episodes and allergic sensitization, and diminishing productive work and school days.[760,761,762,763]

> "Climate change is a public health crisis – impacting our weather and environment, along with the quality of the air we breathe, the water we drink, and the food we eat. The most vulnerable members of our communities – children, people of color, the poor, people with disabilities or chronic diseases, and the elderly – are the ones who suffer the most."[852]
>
> **— Health Care Climate Council**

It is also important to recognize the serious effects that air pollution from fossil fuel combustion and industrial processes has had on human health for generations. Air pollutants—like ozone and particulate matter—released or derived from internal combustion engine vehicles, fossil fuel power plants, industrial sites, catastrophic wildfires, and commercial and residential buildings can severely damage the lungs and cause heart disease and death. Although air pollution is not usually listed as a primary or secondary cause of death on death certificates, it is a risk factor associated with many other diseases. The elderly, people with disabilities, and people with underlying health conditions are especially

susceptible.[764] Researchers looking at these root causes found that air pollution caused 8.8 million premature deaths worldwide in 2015, making it the leading cause of premature death—ahead of smoking, HIV/AIDS, and malaria.[765,766,767] Two-thirds of all premature deaths globally are partially attributable to human-made air pollution, primarily from fossil fuel use.[768] In 2018, nearly 50 percent of U.S. residents (150 million people) lived in communities where air pollution exceeds air quality standards.[769] Emissions related to the buildings sector (commercial and residential) are the leading cause of premature death in the United States, accounting for over 60 percent of premature deaths in Massachusetts and other New England states.[770] Climate action that results in reduced fossil fuel use can improve air quality and, as a result, reduce these adverse health outcomes and save lives. Efforts to reduce pollution are an extremely urgent health intervention—the mortality rate from air pollution alone is three times higher than other avoidable environmental risks, such as unsafe water, hygiene, and sanitation.[771]

Air pollution may also exacerbate or elevate the risk of other health conditions. The COVID-19 pandemic is a recent example of how pollution and health conditions are linked. One study found that nearly 80 percent of COVID-19 deaths in four countries came from the areas with the highest concentration of air pollution.[772] Furthermore, long-term exposure to a higher level of air pollution from cars, refineries, power plants, and other sources was associated with an 8 percent increase in the COVID-19 death rate.[773] This suggests the severity of COVID-19 cases may be directly influenced by air pollution, a trend that is also observed in a variety of respiratory infections.

HEAT EXPOSURE. Climate change is making the country hotter, with more frequent and more extreme heat waves.[774] The average temperature in the United States has increased by 1.3-1.9 degrees Fahrenheit total since 1895, with most of the increase happening since 1970.[775] 2019 was the second-hottest year ever recorded, with the month of July coming in as the hottest month ever on record.[776] Heat waves are the top cause of weather-related deaths in the United States.[777] As the climate continues to warm, there will be a dramatic increase in dangerous heat index days in the United States, with estimates suggesting the number of days with 105-degree heat index will triple by 2050.[778] Heat extremes not only cause heat stroke, but also exacerbate cardiovascular and respiratory complications,[779] kidney stones,[780] and preterm birth.[781] A study of 32 million U.S. births found that women exposed to high temperatures face a higher risk of premature, underweight, or stillborn babies, with a disproportionate impact on Black women.[782]

VECTOR-BORNE AND INFECTIOUS DISEASES. Climate change and rising temperatures will increase the spread of vector-borne diseases, which are carried by insects or animals like mosquitoes and ticks. Rising temperatures allow vectors to spread into higher altitudes and new regions further from the equator. Mosquito-borne diseases like malaria, dengue, West Nile virus, and Zika virus will likely increase.[783,784,785] Already, the incidence of Lyme disease has dramatically increased in the northeastern United States, in part due to rising temperatures that allow ticks to survive winter months.[786] There were 10,000 cases of Lyme disease in the United States in 1991; now there are more than 40,000 cases per year, with evidence that some of the increase resulted from warmer winters due to climate change.[787,788] In addition, infectious diseases that are transmitted from human to human but which originate in animals, like the recent coronavirus that causes COVID-19, may increase as climate change shifts habitats and brings humans into closer contact with wildlife.[789,790] Deforestation and farmland and urban expansion—which can be driven by climate impacts like extreme drought or flooding—can increase contact between humans and wildlife, raising the chance of disease transmission. The changing climate will require new precautions to minimize vector-borne and infectious diseases.

FOOD SAFETY. Climate-induced extreme weather has the potential to make our food less safe. For example, after Hurricane Florence flooded a massive area of cropland in North Carolina, state authorities warned residents of the dangers of selling and consuming contaminated food products from fields flooded by nearby rivers, creeks, or streams.[791] Wet fields can also promote molds and fungi that produce toxins and cause infection. Researchers warn that in Iowa, "rising humidity…and longer periods of rain and dew remaining on foliage…increase the growth of molds and fungi and contribute to increases in infections and mycotoxin contamination in both pre-harvest and stored grain."[792]

Climate change can also cause a host of systemic food safety risks simply because of rising temperatures. As the planet warms, our food will become less safe and more contaminated as certain pathogens and toxins become more prevalent.[793] Some bacterial pathogens like *Salmonella* prefer higher temperatures, so food spoilage rates may increase as temperatures rise.[794] Molds and fungi that produce potentially lethal toxins, including mycotoxins, are spreading northward to cropland in new geographic regions around the world.[795] The nutritional quality of food supplies may also decline, as rising carbon dioxide concentrations can negatively affect the nutrient content in crops.[796] Rising temperatures will increase heavy metal uptake into crops as well, a major concern for arsenic leeching into rice.[797]

Climate change may also increase human exposure to mercury and pesticides. While mercury concentrations in seafood have fallen over the past three decades due to protective standards, warmer ocean temperatures have increased the metabolic activity of fish and led to increased concentrations of mercury in seafood as they consume more prey. [798] Climate change will also increase the range of pests as warmer weather and changing weather patterns allow them to spread to new regions, prompting increased pesticide usage on crops. And accelerated permafrost thawing in the Arctic is releasing large amounts of previously trapped mercury into the soils and fresh waters of Alaska, where it bioaccumulates in wildlife and may soon become a dangerous contaminant in Arctic food supplies.[799]

ACCESS TO SAFE WATER. Extreme flooding driven by climate change can cause sewage overflow, which leads to bacterial and viral contamination in drinking water.[800] Droughts are also becoming more common, limiting access to safe drinking water and even causing groundwater to become contaminated as overpumping pulls in naturally occurring contaminants like arsenic.[801] By disrupting the safety of and access to drinking and wastewater services, climate change can exacerbate other public health crises. Additionally, harmful algae and pathogens that pose a threat to water safety are becoming more common as water temperatures increase. Harmful algal blooms (HABs) occur when warm water holds an excess of nitrogen and phosphorus, often from agricultural runoff, urban runoff, or excessive fertilizer use, which then creates the conditions for toxic algae to grow. HABs are appearing more broadly. For example, HABs in Lake Erie have been steadily increasing over the past decade.[802] In 2014, more than half a million people had to avoid drinking tap water in Toledo, Ohio, due to a serious HAB in Lake Erie.[803]

MENTAL HEALTH. A growing number of national health organizations, including the Centers for Disease Control, National Institutes of Health, American Public Health Association, and the American Psychiatric Association, recognize that climate events can cause stress and anxiety.[804] These mental health impacts can result from dealing with a flooded home due to a hurricane or coping with daily asthma exacerbated by local air pollution. In addition to stress, climate-related disruptions can contribute to mental health conditions like depression and post-traumatic stress.[805] For example, individuals who experienced a flood report higher levels of anxiety and depression, often lasting for several years after the event.[806] As disasters and extreme weather become more frequent, more people will face displacement from their homes, lose their family members, and see their communities disrupted, all of which can contribute to negative mental health outcomes. Children experience the looming threat of climate change particularly acutely, with 57 percent of American teenagers reporting that climate change makes them feel scared.[807]

Figure 1: Health risks from climate change

RISK	CLIMATE DRIVER	EXPOSURE	HEALTH OUTCOME	IMPACT
Extreme Heat	More frequent, severe, prolonged heat events	Elevated temperatures	Heat-related death and illness	Rising temperatures will lead to an increase in heat-related deaths and illnesses.
Outdoor Air Quality	Increasing temperatures and changing precipitation patterns	Worsened air quality (ozone, particulate matter, and higher pollen counts)	Premature death, acute and chronic cardiovascular and respiratory illnesses	Rising temperatures and wildfires and decreasing precipitation will lead to increases in ozone and particulate matter, elevating the risks of cardiovascular and respiratory illnesses and death.
Flooding	Rising sea level and more frequent or intense extreme precipitation, hurricanes, and storm surge events	Contaminated water, debris, and disruptions to essential infrastructure	Drowning, injuries, mental health consequences, gastrointestinal and other illness	Increased coastal and inland flooding exposes populations to a range of negative health impacts before, during, and after events.
Vector-Borne Infection *(Lyme Disease)*	Changes in temperature extremes and seasonal weather patterns	Earlier and geographically expanded tick activity	Lyme disease	Ticks will show earlier seasonal activity and a generally northward range expansion, increasing risk of human exposure to Lyme disease-causing bacteria.
Water-Related Infection *(Vibro vulnificus)*	Rising sea surface temperature, changes in precipitation and runoff affecting coastal salinity	Recreational water or shellfish contaminated with *Vibrio vulnificus*	*Vibrio vulnificus* induced diarrhea and intestinal illness, wound and bloodstream infections, death	Increases in water temperatures will alter timing and location of *Vibrio vulnificus* growth, increasing exposure and risk of water-borne illness.
Food-Related Infection	Increases in temperature, humidity, and season length	Increased growth of pathogens, seasonal shifts in incidence of *Salmonella* exposure	*Salmonella* infection, gastrointestinal outbreaks	Rising temperatures increase Salmonella prevalence in food; longer seasons and warming winters increase risk of exposure and infection.
Mental Health and Well-Being	Climate change impacts, especially extreme weather	Level of exposure to traumatic events, like disasters	Distress, grief, behavioral health disorders, social impacts, resilience	Changes in exposure to climate or weather related disasters cause or exacerbate stress and mental health consequences, with greater risk for certain populations.

Source: https://health2016.globalchange.gov/

Marginalized populations face disproportionate impacts

The root causes of health and environmental inequalities are largely the same. Energy, transportation, food, agriculture, land use, and the built environment significantly shape our living conditions and are major contributors to climate pollution. Socioeconomic status, race, and ethnicity have influenced how these systems were constructed. Over time, inequities in the distribution of money and power, discriminatory practices, structural racism, and disinvestment in some communities have led to higher levels of pollution and less access to health resources.[808] These compounding factors have caused low-income communities and communities of color to disproportionately experience the impacts of climate change on health.

Climate exposure, sensitivity, and resilience[i] vary across populations and communities, with low-income families, people of color, children, the elderly, and people with disabilities facing greater health risks.[809] For example, urban areas experience increased heat due to less tree cover, more pavement, and more buildings. But even within a city, low-income neighborhoods are more likely to be hotter compared to wealthier neighborhoods, with some areas experiencing as much as a 10-degree difference.[810]

People with a greater number of underlying health conditions are at even higher risk of health complications.[811] For example, asthma is an underlying condition that can exacerbate heat exposure and increase the risk of death during heat waves.[812,813] Asthma rates were 17 percent higher in Black populations than white populations in 2000.[814] In addition, Black and Brown people are more likely to live close to sources of greenhouse gas and air pollution emissions, and increased levels of pollutants like particulate matter lead to higher mortality rates in these neighborhoods.[815,816] In addition to facing increased risk of adverse health impacts, people in these frontline communities also tend to be the least able to avoid heat hazards through going indoors, using air conditioning, or avoiding outdoor work.[817,818,819]

i Exposure refers to how long, how often, and how intense the stressor is, such as how often a person experiences days with high temperature. Sensitivity refers to the degree to which a person is affected by a stressor, with an 80-year-old person being more sensitive to heat stress than a 25-year-old. Resilience refers to the ability to avoid or adjust to potential hazards. For instance, an older person could move indoors to an air-conditioned room during a heat wave, as long as they are able to afford the electricity bill and have a place to live.

Certain people may also lack access to capital and other resources needed to avoid and prepare for the health risks of climate change. This can include people of color, pregnant people, young children, people with disabilities, people experiencing homelessness, displaced people, uninsured or underinsured people, and those with limited financial resources. Already faced with significant challenges in navigating daily life, these individuals and their communities are ill situated to mitigate climate risks. For example, Native communities can be especially at risk, as changing weather and sea-level rise have already contributed to forced community displacement, threatened access to clean drinking water, and decreased food security—impacts that have also increased mental stress and illness and worsened infectious diseases.[820] Climate change is exacerbating social and health inequities in Native communities, amplifying historic trauma, worsening chronic illness, and threatening cultural practices and ways of living that are critical for the health and well-being of these communities.[821]

Our health care facilities are at risk

Extreme weather can disable our hospitals and other health care facilities right when communities and patients need them the most. Flooding, loss of power, and structural damage at a hospital during a storm can be a life-or-death situation. In the United States, hospitals are 31 years old on average, and many were built next to rivers or the coast for water supply and sewage discharge.[822] The age and location of hospitals places them at great risk. Events like Hurricane Katrina (2005) and Hurricane Sandy (2012) demonstrated how flooding and power loss impact health care systems. During Hurricane Katrina, 23 of the 26 hospitals in New Orleans were evacuated due to flooding and many remained closed for months. Loss of access to health care facilities may have resulted in 1,800 deaths after the hurricane.[823]

Outpatient facilities are also affected during extreme weather. During Hurricane Katrina, 94 dialysis facilities were closed due to flooding or power loss, affecting more than 6,000 patients.[824] People living with chronic health conditions need to have regular access to health care, and severe disasters like Hurricanes Katrina and Harvey left thousands of cancer patients and others with chronic conditions without needed treatment and scrambling to find care in other facilities.[825]

In addition, manufacturing facilities that produce critical medical supplies and drugs are at risk from climate-related extreme weather. Drug manufacturers are not required to have any contingency plans in case of disaster or redundancy in their facilities, no matter how critical the drug.[826] Damages from Hurricane Maria in 2017 put one of the major manufacturers of saline out of service, leading to severe shortages across the United States.[827] The manufacturing plant in Puerto Rico supplied roughly 50 percent of U.S. hospitals with this product, and without planning or redundancy, a single facility outage had reverberating effects across U.S. hospitals.[828]

OPPORTUNITIES AND PROGRESS

Climate mitigation results in direct health benefits

The primary way to mitigate climate change is to reduce greenhouse gas emissions across the economy. By addressing greenhouse gas emissions from power plants, cars and trucks, factories, and other sources, the United States can reduce its contribution to global climate change, help avoid future climate impacts, and protect public health. These direct health benefits largely come from the accompanying reduction in co-pollutants like air toxics and particulate matter.

> "A look at the forecasts in the U.S. government's National Climate Assessment for the year 2100 makes you realize how many lives could be saved, how many illnesses could be prevented, by doing what we already know how to do to mitigate climate change. Reducing greenhouse gases in the Earth's atmosphere may be the greatest public health intervention ever."[853]
>
> **—Ari Bernstein, MPH**
> *Associate director of the Harvard University Center for Health and the Global Environment*

Reducing overall emissions to save lives and health care costs

Globally, phasing out fossil fuel pollution could save as many as 3.6 million lives per year.[829] Domestically, eliminating fossil fuel pollution can save 100,000 lives and $880 billion annually.[830] Savings would come in the form of healthier lives, lower health care costs, and higher work productivity. The United States currently has one of the most expensive health care systems in the world, spending on average 18 percent of its gross domestic product on health care for a total of $3.6 trillion in 2018.[831]

With reduced greenhouse gas emissions and co-pollutants, health care spending related to air pollution and climate change would decrease due to the decline of acute illness and mortality—potentially resulting from weather disasters, heat waves, or disease outbreaks—and chronic illness such as asthma, heart disease, and depression. For example, a California case study determined that the state would have saved $193 million in health care costs in 2005 if it had met federal clean air standards for particulate matter and ozone.[832]

If the United States meets the targets of its Nationally Determined Contribution to the Paris Agreement, 295,000 deaths from lung cancer, heart attacks, or respiratory disease could be prevented by 2030.[833] A reduction in greenhouse gas emissions is accompanied by a reduction in particulate matter and ozone concentrations, which drives down the number of premature deaths due to air pollution.[834]

PROTECTING KIDS' HEALTH BY REDUCING EMISSIONS AT SCHOOLS

Many students start and end their weekdays riding on older, polluting buses. According to the Environmental Protection Agency, riding a half hour to two hours a day on one of these buses puts the health of students at significant risk.[854] With asthma affecting 6.3 million school-age children throughout the country, it is essential that Congress help communities not only transition school bus systems to cleaner, zero-emission vehicles, but also work to increase energy efficiency and upgrade heating, ventilation, and air conditioning units to improve air quality in schools.[855] Schools across the country recognize the importance of reducing emissions to the health of their students, as well as their bottom line. For instance, the Des Moines Public School District in Iowa has been working to teach its students about the importance of energy efficiency, and the district continues to make smart investments in its schools to improve efficiency and reduce emissions. Since 2008, the district has reportedly saved $19.3 million and prevented the release of more than 31,500 metric tons of carbon dioxide emissions.[856]

Strengthening emissions standards for vehicles and power plants

The Clean Air Act requires the Environmental Protection Agency (EPA) to set standards that address pollution—including greenhouse gases—from sources like power plants, cars, and trucks. Over decades, these standards have dramatically reduced pollution while saving countless lives. Yet the Trump administration has attacked many of these life-saving standards. The administration has undermined the existing Mercury and Air Toxics Standard, a rule that reduces toxic air pollution from power plants. According to the EPA's own estimation, this standard saves up to 17,000 lives per year, with cost savings of $60-140 billion per year.[835] Additionally, the Trump administration is rolling back vehicle fuel economy and greenhouse gas emissions standards that help reduce the United States' carbon footprint. The vehicle standards rollback could result in 18,000 premature deaths by 2050 and $190 billion in additional health-related costs due to particulate pollution, according to one analysis.[836] Strengthening pollution standards, rather than rolling them back or undermining them, can reduce greenhouse gases, mitigate long-term climate impacts, and deliver concrete public health benefits.

Reducing emissions within the U.S. health care sector

While provision of health care is an essential public good, the health care sector is responsible for 10 percent of all U.S. greenhouse gases.[837] Health care facilities can take steps to reduce greenhouse gas emissions that would also reduce operating costs and promote resiliency, like on-site solar or other distributed renewable generation. Energy systems that combine heat and power can improve a hospital's resilience to power grid disruptions while also reducing emissions and costs.[838] Furthermore, the industry's supply chain—which includes the production of drugs, medical supplies, and medical equipment—is the biggest contributor to its carbon footprint.[839] Core emissions from heating, fuel, and electricity are the next largest source.[840] By adopting waste-reducing and energy efficiency measures, hospitals could save $15 billion over ten years—money that could be reinvested to secure better care for patients and communities.[841] Not only will efficiency improvements drive down energy costs, but upgrading health care infrastructure will make facilities more resilient to future extreme weather events. The federal government can provide funding, tax incentives, and financing that health care facilities can use to invest in clean energy and resilience.

HOSPITALS LEADING THE WAY: BOSTON MEDICAL CENTER CASE STUDY

Hospitals nationwide are taking steps to reduce their emissions. The Boston Medical Center (BMC) is one hospital that is leading the way and is on track to be carbon neutral by the end of 2020. Energy-saving measures such as upgrades to heating, cooling, and ventilation, efficient lighting, and a new biogester to compost food waste reduced BMC's annual energy bill by $7.2 million in 2019, a drop of 40 percent from 2011 levels.[857] Additionally, BMC has installed a 2-megawatt rooftop combined heat and power plant that generates much of its electricity and ensures electrical grid independence in case a major disaster shuts down the grid. To date they have reduced emissions by 50 percent, but BMC continues to work towards its goal of carbon neutrality by partnering with a solar power farm to buy clean electricity—an achievement that would make it the first hospital in New England to have a carbon-neutral energy supply.[858] Additionally, BMC installed a 7,000 square foot rooftop farm that produces 5,000 pounds of food during growing seasons, which are used for patient meals.[859] City and state support was essential for the hospital's major renovation project, with state grants helping provide for some of the upfront capital. Overall, the emissions reductions from BMC are equivalent to removing 25,000 cars from the highway each year.[860] These advances help protect the climate, ensure the hospital can continue functioning in the event of a disaster, and protect the health of patients and surrounding communities.

Climate adaptation reduces risks and improves health

By taking steps to adapt to the climate impacts we can no longer avoid, the United States can further protect public health and address health inequities.

Reducing vulnerability by strengthening health care coverage and public health measures

While eliminating greenhouse gas emissions is the most effective long-term strategy to reduce climate-related health impacts, improving overall public health will lower the cost of adaptation and reduce the magnitude of climate damages at the human level. The current health status of the population is one of the most important predictors of how much public health will be affected by climate change.[842] Therefore, one way to address the health impacts of climate change is to improve core public health measures that reduce the burden of disease and ensure access to safe food and water. Every U.S. resident should have guaranteed access to affordable, high-quality health care, safe housing, nutritious food, and clean water and sanitation. Furthermore, federal, state, Tribal, and local health departments and environmental health programs should be strengthened to bolster community health and reduce the burden of preventable diseases, while ensuring every person receives essential health services like vaccinations. Guaranteeing that every community in the United States has a strong public health system—and that every person has access to health services, housing, and other necessities—can promote resilience to any future health threats, including those caused by climate change.

Developing preparedness and response plans

Building strategic plans that address the impacts of climate change and severe weather will be important to protect public health. State and local governments should create plans that identify a community's risk, the associated health impacts, and the populations who are most vulnerable. Strategic plans must be accessible to all residents—one study found that 79 percent of people with disabilities would be unable to quickly evacuate in response to a disaster.[843] Plans must also be available to residents in all necessary languages. Having health care and public health professionals participate in the planning process will make sure a community is well prepared for a crisis and able to communicate essential health information to residents. The federal government needs to provide more financial and technical assistance to public health and health care professionals, first responders, health care systems, states, Tribes, territories, and municipalities as they prepare for the impacts of climate change. The federal government can do this by expanding programs like the Centers for Disease Control and Prevention (CDC) Climate and Health Program, which is only able to work with a limited number of states because of a lack of available funding. Specifically, the CDC's Climate-Ready States and Cities Initiative helps communities identify likely climate impacts, associated potential health effects, and their most at-risk populations and locations. This information enables communities to make plans that address gaps in critical public health functions and services. The federal government should also support the implementation of vulnerability mapping, which overlays climate projections with health demographics for an area, allowing public health and government officials to target communities for intervention or develop policies to improve preparedness.

Building health system capacity for disaster preparedness

As threats from climate change continue to mount, the United States needs to invest more in disaster preparedness and resilient infrastructure to protect human health, especially in public health systems and health care facilities. The federal government needs to invest in physical and natural infrastructure to protect buildings from disasters; more accurate modeling to predict weather and health events; emergency management systems; contingencies for surge capacity to deal with climate hazards; and resident notification systems. Health care facilities must be updated with features to mitigate and prepare for the risks from climate change, such as hurricane-resistant structures, basement pumps to prevent flooding, flood doors, elevation of first floor facilities above 100-year flood levels, and roof-mounted critical infrastructure.[844] Facilities also need plans for potable water access during times of drought and natural disasters.

Importantly, existing and new health care facilities need to take into account updated floodplain maps and ensure flood-resistant construction. Existing hospitals on floodplains should upgrade their infrastructure to protect the building from any extreme weather. For example, Spaulding Rehabilitation Hospital in Boston was under construction when Hurricane Sandy hit, but lessons learned from Katrina ensured it suffered only minimal damage. It was the first building on the city's waterfront to account for projected sea-level rise and is one of the most climate-resilient hospitals in the United States.[845] The federal government needs to require hospital vulnerability assessments, emergency preparedness plans, and building codes that are based on region-specific climate projections, done with community consultation.

Establishing early warning systems

To protect Americans from climate threats, the United States should implement early warning systems to notify residents about emerging threats, similar to the tornado warning systems used in many parts of the country. For example, during an incoming heat wave, cities should have the capacity to issue a heat wave alert and notify all residents.[846] Local officials should broadcast information in multiple languages and multiple means to accommodate all residents and ensure information gets to those who are blind, have low vision, are deaf, or are hard of hearing. Local officials should provide shelters and resources to help residents cope with the event. These early warning systems can save lives and ensure that residents are prepared to respond to deadly events. Some cities have already implemented extreme heat warning systems, including Philadelphia, Phoenix, and Chicago, with demonstrated success in saving lives.[847]

Reducing the risk of mental health impacts

Adapting to climate change will also require improvements to the national mental health system. The United States needs to incorporate planning for individual and community resilience into climate change preparedness plans, as psychological well-being is often left out of broader climate-health planning efforts. Communities can expand mental health infrastructure, provide additional services for vulnerable residents, share information about good coping skills, establish plans for disaster preparedness, and support programs that foster community and social cohesion.[848] All of these steps can reduce the risk of negative mental health outcomes. The federal government can support community efforts by increasing funds for the Substance Abuse and Mental Health Services Administration (SAMHSA) block grants and the National Child Traumatic Stress Network, both of which were created by Congress to support community-based programs in mental health.

Investing in climate change and health research, monitoring, and surveillance

More data will help us better understand the adaptation needs and health benefits of climate action. In particular, investments in pollution monitoring and research into pollution's impact on health can identify the contribution of each pollution source, provide information about successful interventions, and help us assess progress towards goals. Additionally, enhanced forecasting, modeling, and monitoring of infectious disease spread and environmental health indicators can play an important role in our response to climate-driven public health challenges. Congress should support all of these measures and develop a national action plan.[849]

Supporting city, Tribal, and state infrastructure that reinforces health

The federal government should direct infrastructure investments to states, Tribes, and municipalities that support healthier lifestyles while mitigating climate change. These investments can include low-cost public transportation, more green space, and energy-efficient buildings. These measures will reduce pollution and rates of chronic disease while also reducing climate risks. The federal government should prioritize investments in public transportation that connect housing and jobs and provide convenient access to

medical care, healthy food options, and other basic services.[850] Policies must ensure that expanded public transportation does not lead to increased air pollution, especially in low-income neighborhoods that often have higher concentrations of bus depots. Transportation investment must prioritize green transportation options that promote health rather than erode it. Furthermore, the government should prioritize investments in bicycle and pedestrian infrastructure that will make biking and walking safer and more convenient.

The federal government must collaborate and consult with local communities in order to invest in urban green spaces, such as parks, trees, playgrounds, green streets that incorporate vegetation to capture storm water runoff, and public plazas with vegetation. More green space will enhance cities' resilience to storms, reduce the temperature extremes from the urban heat island effect, and promote healthy communities. Finally, the United States should invest in and provide incentives for energy-efficient buildings, which not only reduce greenhouse gas emissions and air pollutants, but also improve the physical and mental health of workers through enhanced natural light, noise reduction, and higher air quality.[851]

MILITARY READINESS

> Climate change poses direct threats to the safety of our service members and the effectiveness of our military operations. We must act now to increase the military's resilience to a changing climate and transition to cleaner fuels and energy sources as a matter of mission assurance and national security.

The Department of Defense (DoD), the agency charged with protecting our national security, observed as early as 1990 that climate change threatens our military readiness.[861] Recent reports show that the impact of climate change on mission assurance is an ongoing concern.[862] Testifying before the Senate Armed Services Committee in 2019, then-Secretary of Defense James Mattis noted, "climate change is a challenge that requires a broader, whole-of government response…[and] is impacting stability in areas of the world where our troops are operating today."[863]

Despite consensus[864] on the risks climate change poses to global and national security, DoD has taken only limited action to assess and mitigate climate-related threats to its mission. In 2018, the Army War College—one of the Nation's premier universities focused on security—stated that DoD "is precariously unprepared for the national security implications of climate-induced global security challenges."[865] An incomplete accounting of how climate change affects military personnel and installations leaves our service members at risk, and jeopardizes our interests around the globe. Congress and military leaders must immediately take steps to improve DoD's preparedness for climate threats, which should include:

- ✔ Incorporating climate projections into master planning and installation planning documents for all U.S. military installations.
- ✔ Developing uniform guidance on how to use climate projections in facilities planning.
- ✔ Including climate provisions in every National Defense Authorization Act (NDAA).
- ✔ Improving interagency cooperation among defense, intelligence, and civilian agencies on climate change data collection, analysis, and forecasting.
- ✔ Supporting continued DoD research into new technologies that reduce our military's dependence on fossil fuels.

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> "If you look around the world and you ask security experts, water scarcity is one of the dynamics that has economic impacts. It's one of the things that creates tension and creates stress on a government. And when that government has got a limited capacity to do its basic functions and you add a stress like that, it makes everything worse."[902]
>
> **— John Conger**
> *Director, Center for Climate and Security*

It is important to note that climate change itself will also be a key source of global instability and conflict. The U.S. intelligence community concluded in its January 2019 Worldwide Threat Assessment that climate change is "likely to fuel competition for resources, economic distress, and social discontent through 2019 and beyond."[866] In December 2018, the Government Accountability Office (GAO) said that "tensions over climate change will grow," since "more extreme weather, water and soil stress, and food insecurity will disrupt societies" and "sea-level rise, ocean acidification, glacial melt, and pollution will change living patterns."[867]

We are already seeing climate-induced armed conflict. Syria's ongoing civil war was sparked at least in part by the civil unrest that followed a historic drought.[868] And as climate disasters intensify, resource scarcity and mass migration will threaten to overwhelm the United States' capacity to respond to humanitarian disasters.[869] As DoD takes crucial steps to bolster its resilience to climate impacts, we must not forget that the most effective national security approach to climate change is to stop warming in the first place—and to help the most vulnerable countries become more resilient against the climate impacts they can no longer avoid.

RISKS OF INACTION

Climate change poses significant risks to U.S. military installations

Climate-induced extreme weather events pose immediate risks to the safety of key military installations and training ranges domestically and internationally. In January 2019, DoD identified that the majority of 79 installations designated "mission assurance priority bases" are vulnerable to climate risks.[870]

The United States military requires installations for operations, administrative activities, training, and to support a range of missions. This translates to real property across approximately 24 million acres, with nearly 600,000 structures under Pentagon management worldwide.[871] The replacement value for this infrastructure has been estimated at more than a trillion dollars.[872] Although DoD has taken some action to protect these bases from climate change, like updating building codes and conducting some vulnerability assessments,[873] it must do more. In 2019, the GAO observed that DoD installations "have not consistently assessed risks from extreme weather and climate change effects or consistently used projections to anticipate future climate conditions," in part "because they lack guidance on how to incorporate projections into their master plans."[874]

DoD's own January 2019 report indicated that two-thirds of the 79 military bases surveyed within the United States currently face risks from recurrent flooding, with more than half vulnerable to drought or wildfires.[875]

Table 1: Summary of climate-related vulnerabilities at 79 bases surveyed[908]

		RECURRENT FLOODING		DROUGHT		DESERTIFICATION		WILDFIRES		THAWING PERMAFROST	
Service	# Installation	Current	Potential	Current	Potential	Current	Potential	Current	Potential	Current	Potential
Air Force	36	20	25	20	22	4	4	32	32	-	-
Army	21	15	17	5	5	2	2	4	4	1	1
Navy	18	16	16	18	18	-	-	-	7	-	-
DLA	2	2	2	-	2	-	-	-	-	-	-
DFAS	1	-	-	-	1	-	-	-	-	-	-
WHS	1	-	-	-	-	-	-	-	-	-	-
Totals	**79**	**53**	**60**	**43**	**48**	**6**	**6**	**36**	**43**	**1**	**1**

Although this survey makes important observations about the current risks to *some* bases, it does not give a full characterization of the risks facing *all* of DoD's hundreds of installations. Notably absent from this survey are bases operated by the Marine Corps: DoD only surveyed Army, Air Force, and Navy installations. Nor does this survey include DoD property in foreign countries, or outline any plan to address the vulnerabilities.[876] The report—which Congress mandated in the 2018 National Defense Authorization Act (NDAA)—was also supposed to provide a list of the top 10 installations most vulnerable to climate impacts, a requirement DoD ignored.[877] These omissions call into question DoD's grasp on the climate-related risks it faces.


Tropical Storm Florence on September 15, 2018

Ignoring the potential costs of repairing vulnerable installations comes at a high price to taxpayers. A 2019 GAO report highlighted the rising cost of repairs to military facilities impacted by extreme weather events. For example, in the course of one month in 2018, Hurricanes Florence and Michael caused more than $6 billion in combined damage to Camp Lejeune and Tyndall Air Force Base.[878]

While damaged bases may rebuild over time, the lost training time and impact on readiness are harder to quantify—and cannot be recovered. In a February 2019 letter to the Secretary of the Navy, then-Commandant of the U.S. Marine Corps, General Robert Neller, wrote that because of the damage from the storms, one-third of the entire combat power of the Marine Corps "is degraded and will continue to degrade given current conditions."[879]

Additionally, DoD installations, including those in the United States, support worldwide missions. Power disruptions from natural disasters can have a major impact on mission assurance. Most bases rely on diesel generators for backup generation, with fuel coming from off base. In the event bases are unable to secure fuel from outside the fence in a crisis, DoD is unprepared for prolonged power outages.[880] DoD needs to do a better job mapping its vulnerabilities at installations that house critical assets and building on-base renewable generation to ensure resiliency against climate-related disruptions.

Yet, climate risks to military readiness are not limited to domestic installations. Many of the bases our military operates around the world face imminent threats associated with climate change. Their risks are distinct because the facilities on these bases cannot always

be moved. This is especially true for bases on island nations. For example, the island of Diego Garcia in the Indian Ocean is a critical logistics hub for U.S. and British forces in the Middle East and East Asia and houses important Air Force Satellite Control Network equipment. It is one of our most important installations for national security, and one of the most vulnerable military installations to climate change. Sitting only 6.5 feet above sea level, this facility will face increasing tropical cyclone intensity, flooding and erosion from sea-level rise, and salinization of freshwater supplies.[881]

Similarly, U.S. bases on the Marshall Islands are home to the Army's world-class range and test facility, the Ronald Reagan Ballistic Missile Defense Test Site. This asset is critical in strengthening our ballistic missile defenses and space operations. By no later than mid-century, the Marshall Islands can expect to flood annually and lose potable water, rendering them uninhabitable within just a few decades.[882] In 2015, DoD broke ground on a nearly $1 billion radar installation, called Space Fence, on an atoll in the Marshall Islands. An Associated Press investigation found that neither DoD nor its contractor, Lockheed Martin, considered sea-level rise when choosing the site, even after warnings from the Marshall Islands' environmental agency.[883] DoD's 2014 environmental assessment ran over 100 pages but made no mention of climate change; just a single line stated, "Based on historical data, there are no anticipated issues with ocean tide and/or wave flooding."[884]

Ronald Reagan Ballistic Missile Defense Test Site

Certain geographic locations within the United States and around the world hold unique military value. As the above examples highlight, many of these same locations are particularly vulnerable to the effects of global climate change. With this in mind, it is critical that DoD work to mitigate the risks facing these bases and incorporate climate change projections into installation design. If bases are damaged or partially shut down due to climate impacts, our adversaries have an opportunity to capitalize on the absence of U.S. military presence and the degraded readiness of our personnel.

Climate change jeopardizes the safety of military personnel

Beyond military infrastructure, climate change severely impacts military personnel by creating heat and water scarcity risks.

HEAT. Rising temperatures around the world are creating operational constraints for military personnel that DoD has struggled to effectively mitigate. A joint report from NBC News and InsideClimate News found 1,766 cases of heatstroke or heat exhaustion among active-duty service members in 2008; ten years later, in 2018, that figure had climbed to 2,792, an increase of almost 60 percent in a decade.[885] In the Marine Corps, the rate of heatstroke more than doubled over that period.[886] In addition to the lethal danger this poses to our service members, it has significant financial costs: health impacts from heat cost the military nearly $1 billion from 2008 to 2018.[887]

InsideClimate News and NBC News' investigation found that "despite acknowledging the risks of climate change, the military continues to wrestle with finding a sustainable, comprehensive strategy for how to train in sweltering conditions."[888] If the military cannot adapt to training and operating in extreme heat, it will degrade operational readiness and kill troops.

WATER SCARCITY. Rising temperatures also contribute to water scarcity for service members. Hydration is a key safety concern for military personnel, especially in the overseas environments that have characterized our military engagements over the past several decades. According to the Army War College, the Army "is precipitously close to mission failure concerning hydration of the force in a contested arid environment."[889] The Army is incurring high costs by packing and shipping water bottles to keep troops hydrated. Relying on this practice is an unsustainable method for maintaining service members' health.

It is unclear if the military understands the scope of this issue and its impact on personnel. GAO found that DoD "does not have assurance that it is using reliable information regarding which installations are at risk for water scarcity."[890] More than 100 active-duty military installations in the contiguous United States alone are at risk of water scarcity.[891] For example, at Mountain Home Air Force Base, Idaho, service members and their families were told to curtail water use in 2017 and 2018; other bases already experiencing water shortages include F. E. Warren Air Force Base, Wyoming, and Marine Corps Air Station Yuma, Arizona.[892]

RELYING ON FOSSIL FUELS NEGATIVELY IMPACTS MISSION READINESS AND INCREASES CASUALTIES

Fuel convoys take a significant toll on military operations in terms of costs, logistics, and lives lost.

Fuel transport missions are uniquely dangerous because logistical and infrastructure complexities can leave military personnel vulnerable. Enemies frequently target oil convoys because the sheer size of resources transported is often difficult to mask and the convoys move slowly, especially on poorly maintained roads.[903]

From 2001 through 2010, more than 50 percent of the approximately 36,000 total U.S. casualties in Operation Enduring Freedom and Operation Iraqi Freedom were attributable to hostile attacks during fuel transport missions.[904] U.S. fuel supply convoys were also a frequent ambush target in the Korean War and Vietnam War.[905]

The challenges of bulk fuel operations have been particularly acute in Afghanistan, where narrow, exposed mountain roads connect forward operating bases—ideal terrain for ambushes. Due to these dangerous constraints, fuel transport is costly and challenging, with units often relying on aerial delivery. While the Army sometimes uses private contractors to deliver fuel, there are often significant delays in delivery.[906]

Fossil fuel dependence imposes alarming risks on our deployed service members. As DoD's Defense Science Board noted, "the air and ground delivery of liquid fuel has been at significant cost in both lives and dollars," which "gives credence to DoD initiatives to evaluate and deploy alternatives to petroleum-based fuel systems."[907] Deploying renewable energy at installations in combat zones can reduce fuel consumption, thereby saving service members' lives.

PROGRESS AND OPPORTUNITIES

Congress can direct DoD to address the impacts of climate change

Increasing climate resilience at our military installations

Congress must direct DoD to incorporate climate projections into its master planning and related documents for every military installation. All master plans must include an assessment of the specific risks from extreme weather and climate change facing the installation, and plans to address those risks as appropriate.

Congress must accompany this directive with guidance on how to use different climate projections and require all DoD installations to integrate this guidance into facilities planning and site-specific climate projections. DoD should include this guidance in its Unified Facilities Criteria (UFC), which it uses for planning, design, construction, maintenance, and operations.

Based on a requirement in the 2019 NDAA, in 2018 DoD updated its UFC on master planning to specify that climate projections must be incorporated into new military construction or modifications.[893] However, military installations have not consistently implemented this new requirement—often because they do not know how. GAO found DoD "does not provide guidance to installations on how to use climate projections, such as what future time periods to consider and how to incorporate projections involving multiple future scenarios, nor does it identify the specific types of projections to use."[894]

The 2020 NDAA included provisions directing DoD to assess climate risks to military installations and surrounding communities, improve UFC to promote resilience in new construction, and other promising measures.[895] Congress must build on this momentum in every NDAA going forward, and prioritize climate adaptation and resilience at installations and in the communities outside the fence that support military families and installation operations.

Investing in emerging technologies

DoD should use its considerable research and development capabilities, such as the Defense Advanced Research Projects Agency (DARPA), to address the U.S. military's climate vulnerabilities. DARPA focuses its strategic investments in four areas: Rethink Complex Military Systems; Master the Information Explosion; Harness Biology as Technology; and Expand the Technological Frontier.[896] Congress should mandate a fifth area that prioritizes addressing climate-related risks to infrastructure and personnel.

The 2020 NDAA allocated $8 million towards researching new technologies to capture carbon from air and seawater and convert it into clean fuels. Such technologies could serve a climate mitigation role by capturing carbon, while equipping the military with resources to reduce fossil fuel dependency.[897] Congress should continue its support for such initiatives.

Reducing fossil fuel consumption

Congress must direct the military to dramatically reduce the energy consumption of its major weapons system, its dependence on fossil fuel-generated electricity, and its use of conventional jet fuel.

Some individual bases are heading in this direction. In April 2018, Vandenberg Air Force Base in California announced the completion of a new solar array system that will provide about 35 percent of the base's energy.[898] Through a mission-threat analysis, officials determined that installing the solar array would help address vulnerabilities from potential natural disasters, and avoid any potential supply chain problems that could interfere with coal or natural gas power plants.[899]

Although DoD will remain dependent on oil for conventional jet fuel in the near term, it has opportunities to substantially reduce its fuel consumption by making aircrafts more aerodynamic. In April 2020, the Air Force announced that testing on the KC-135 Stratotanker confirmed vertical wiper blades could reduce aircraft drag by about one percent in cruise conditions.[900] In 2019, the KC-135 consumed almost 14 percent of all Air Force aviation fuel use; implementing this improvement could save up to $7 million in fuel costs annually.[901] Congress can encourage more innovation like this by investing in similar research projects in the NDAA and doing more to ensure competitive awards are going to the most fuel-efficient weapons systems. Climate considerations aside, the benefits to readiness and the warfighter alone justify such improvements.

Prioritizing interagency coordination

Congress must direct the military to address the impacts of climate change through interagency cooperation. Doing so would go a long way towards standardizing a whole-of-government approach to climate change. Given DoD's global reach and monitoring capabilities via both sensors and reconnaissance, it should do more to share information about how the world is changing today. DoD could inform real-world modeling, prediction, and our entire government's understanding of the risks from climate change.

This collaboration should span defense, intelligence, and civilian agencies, and focus on climate change data collection, analysis, and forecasting. Where it is not already routine, the intelligence community's analyses should always include closely synced present-day and near-term climate projections and weather data.

INTERNATIONAL ENGAGEMENT

> The United States must lead the international effort to tackle climate change—not only to meet the scale of the challenge, but to safeguard U.S. interests and advance far-reaching strategic partnerships.

In recent years, the United States has been absent in developing and contributing to a global climate solution. Not because the American people lack initiative or a desire to act, but because President Trump has abdicated American leadership. President Trump's decision to withdraw the United States from the Paris Climate Agreement is just one example of the administration's consistent pattern of abandoning, condemning, and disrupting international efforts to tackle the climate crisis. And it is not just an abandonment of leadership—it is actually an enthusiastic, administration-wide effort to sideline science, tear down pollution safeguards, and promote policy to accelerate the climate crisis.

To protect future generations and rebuild American global leadership, the United States must help lead the global response to the climate crisis. The United States is uniquely positioned to enhance the worldwide ambition necessary to build a safer, stronger planet. American ingenuity and innovation can play a key role in developing new and more effective solutions. The United States can also build strong scientific and security partnerships and reinforce America's ability to lead on other key global priorities. These efforts can foster climate security while creating new opportunities for American leadership, economic growth, and innovation.

The United States has historically been the largest contributor to global greenhouse gas emissions and continues to have one of the highest per capita levels of emissions, underscoring the importance and need for U.S. leadership.[909] But the United States getting its own energy policy right will not be enough. The United States currently only accounts for 13 percent of annual global emissions[910]—which means that international cooperation and global momentum are essential to prevent a climate crisis.

The climate crisis is already reshaping geopolitical relationships and conflicts, international trade, and U.S. economic interests. Severe weather and long-term climate changes are impacting global food security and the health of billions of people. In numerous countries millions of people are being displaced, driven by extreme weather events or diminishing agricultural productivity. A race to take ownership of resources in a quickly melting Arctic is complicating relationships with countries like China and Russia. And severe weather impacts are reverberating through global supply chains, impacting the price and availability of goods and damaging the U.S. economy.[911] Addressing these issues will shape U.S. international engagement in the coming decades. The United States must engage diplomatically and economically to reduce global emissions rather than constantly reacting to the consequences of inaction.

Most importantly, the United States must re-establish its global standing by reinvigorating its commitment to the Paris Agreement and issuing a new, credible Nationally Determined Contribution reflecting science-based targets. The federal government must also leverage all opportunities to spur ambitious global action, including:

- ✔ Supporting climate mitigation, adaptation, and resilience through enhanced U.S. aid programs, financing, and investments.
- ✔ Integrating climate change into key agency decision-making on matters related to foreign policy, national security, and humanitarian assistance.
- ✔ Reengaging in international agreements to reduce global emissions, including the Kigali Amendment.
- ✔ Working with international organizations to reduce emissions from aviation and shipping.
- ✔ Increasing research and development funding to promote international collaboration and global climate monitoring.

U.S. leadership—through both our own decarbonization and cooperation with other countries—can help foster the necessary ambition, drive, and focus to meet the challenge at hand.

"[E]nvironmental instability provides our global adversaries with a powerful new tool for competition with the United States. Increasingly, climate and energy assistance are used as a new tool of influence. As countries in strategically important regions—like South America, the Pacific and West Africa—struggle to address climate change, our adversaries offer them comprehensive climate and energy development packages, while they see the U.S. focusing primarily on military cooperation and pulling out of the Paris Agreement. In the coming years, climate action will be an increasingly important tool of soft power – one where the United States is seen to be absent."[986]

—Andrew Holland

Chief operating officer, American Security Project

RISKS OF INACTION

Climate change is causing global instability and suffering

Global climate change is already harming individuals, communities, and nations by exacerbating food insecurity, spread of disease, and conditions leading to forced migration, among many other present-day impacts.[912] This past decade was the warmest on record worldwide.[913] The 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C underscored the need for urgent action to limit additional future warming and avoid even more extreme outcomes.[914]

The effects of a warming climate do not fall evenly across all locations and communities. Farming and coastal communities, Indigenous peoples, and disadvantaged and vulnerable communities are at disproportionately higher risk of adverse consequences of severe global warming.[915] Regions that are particularly vulnerable include Arctic ecosystems, dryland regions, small island nations, and Least Developed Countries.[916]

A snapshot of different severe risks around the globe shows the scale of the problem:

- Rising temperatures are increasing levels of heat-related death and illness. Already, scientists have been able to attribute recent record-breaking, dangerous heat waves in part to human-induced climate change.[917] Scientists expect extreme heat and humidity events to continue to worsen. For example, without action to mitigate climate change, temperatures in several major Persian Gulf cities are likely to approach and exceed the threshold for survivability before the end of this century.[918]

- Global climate change is exacerbating humanitarian crises and contributing to increased migration. Of the 68.5 million people who were forcibly displaced in 2017, approximately one-third were compelled to move by sudden onset weather events: events made more frequent and severe by climate change, such as flooding, droughts, and intense storms.[919] The March 2019 tropical cyclone Idai alone displaced an estimated 400,000 people in Mozambique.[920] Meanwhile, climate change is causing slow-moving changes that exacerbate existing migration drivers, such as increasing desertification, shifting weather patterns, and other impacts.[921] Recent estimates indicate that by 2050 anywhere from 25 million to 1 billion individuals could be forced to migrate due to climate change or other environmental factors.[922]

© Asian Development Bank

Women displaced by flooding line up to fetch water in the outskirts of Thatta, Pakistan

- Sea-level rise is another driver of climate migration. In the western Pacific Ocean, sea level is rising by as much as 12 millimeters every year, and eight islands are already submerged.[923] In low, narrow atoll nations like Kiribati, the population and infrastructure is concentrated along the coast and directly exposed to the impacts of sea-level rise.[924] Bangladesh, Vietnam, and Thailand may each see areas occupied by approximately a fifth of their populations fall below high-tide levels by the end of the century, even with deep cuts to greenhouse gas emissions.[925] For coastal communities that lack the capacity to adapt and vulnerable island nations, sea-level rise will make relocation inland or migration inevitable.

- South Asian agrarian economies and food security are heavily dependent on the monsoon season. However, climate change is making monsoon rains harsher and less predictable. A World Bank analysis estimated that uncertain rainfall and rising temperatures could depress living standards for half of India's population by 2050 and cost the country 2.8 percent of its GDP.[926] Efforts are underway to decrease uncertainty by improving monsoon forecasting and better incorporating climate change into existing models.[927]

- The steady retreat of glaciers worldwide is a threat to communities that rely on runoff to provide predictable water supply and hydropower. Runoff from highly vulnerable glaciers on the Tibetan plateau is a critical part of the water supply for 1.65 billion people.[928,929] Glaciers in the Andes similarly play a key role in moderating the water supply for downstream communities; their disappearance will leave downstream water users with significantly diminished water supplies during the dry season.[930]

Photo: AusAID

The changing coastal landscape on the island of Abaiang, Kiribati

Panama Canal

U.S. interests abroad are vulnerable to climate change impacts

U.S. ECONOMIC INTERESTS. Climate change impacts abroad have major implications for U.S. businesses, their supply chains, and global trade.

Climate change is disrupting global trade patterns. For example, the Panama Canal, a route used by 5 percent of global trade, is facing growing risks to its water supply, and therefore its operations. 2019 was the fifth driest year in the area in over 70 years, with annual rainfall 20 percent below average.[931] To cope with these challenges, canal operators have required ships to lighten cargo loads, increasing costs and logistical complications for shippers and, ultimately, consumers.[932] These increasing stresses on an already strained resource pose political, economic and social challenges for the Panamanian government, as well as global trade networks that rely on this waterway.

Supply chains for agricultural products, livestock, and seafood are also vulnerable to climate change. In a warming world, large shifts in land-use patterns and management practices will likely be necessary to sustain agricultural productivity and meet demand.[933] Overall catch in global fisheries may decrease and certain fish species may migrate to neighboring countries' exclusive waters, creating challenges for both local communities and global trade in seafood.[934] Globally traded commodities, like corn and coffee, face heightened challenges from a changing climate. Many studies identify high temperatures as a primary driver of decreased corn yields.[935,936] Meanwhile, rising temperatures and changing rainfall patterns are harming the productivity of traditional

coffee growing areas.[937] Impacts on global commodities raise challenges for growers abroad, harming local economies and local livelihoods; they also directly impact major U.S. markets and U.S. consumers.

Manufacturing supply chains face severe disruption from expected increases in extreme weather.[938] For example, the prolonged 2011 flooding in northern and central Thailand—the result of a severe monsoon season and multiple tropical storms—caused at least 680 deaths and widespread damage.[939] In addition to these tragic direct impacts, this disaster caused repercussions worldwide by disrupting global supply chains. The United States, alongside other countries, relies on Thailand as both a supplier and purchaser of goods. Disruptions to Thai hard-drive manufacturing directly cost one U.S. producer $199 million and doubled the cost of hard-drives for customers from Apple, HP, and Dell.[940] Ford Motor Company's Thai production facilities came to a complete standstill in the wake of the flooding.[941]

Health care in the United States is particularly vulnerable to supply chain disruptions caused by climate change and extreme weather. Because U.S. pharmaceutical companies rely heavily on raw materials and other inputs sourced from around the world,[942] the availability of many medications and medical devices is influenced both by extreme weather and by long-term climatic changes. A substantial portion of new drugs approved by the FDA from 1981 to 2014 are either biological, natural products, or contain derivatives from natural products.[943] Pharmaceutical companies like Sanofi have recognized the threat that climate change poses to natural resource availability within their supply chains and developed climate risk and mitigation plans.[944] The small number of suppliers and lack of redundancy for any given product exacerbates the medical supply chain's vulnerability to any source of disruption.[945,946]

The impact of Hurricane Maria on Puerto Rico—while a domestic tragedy—illuminates how a single extreme weather event can severely and broadly disrupt medical supply chains. In its aftermath, many medical manufacturing facilities in Puerto Rico operated at reduced capacity for an extended period of time. Hospitals across the United States experienced shortages of IV bags, intravenous saline, certain antibiotics, and insulin pumps, disrupting medical care and precipitating further shortages of replacement products as medical providers searched for alternatives.[947,948,949]

U.S. SECURITY AND HUMANITARIAN INTERESTS. Climate change is a threat multiplier, exacerbating existing challenges of poverty, environmental degradation, political instability, and social tension around the world. When institutions and governments are unable to manage the stress and absorb the shocks of a changing climate, the risks to the stability of states and societies increase. As a result, climate change will intensify risks to U.S. security interests and also trigger greater demands on U.S. humanitarian aid and assistance.

The 2019 National Intelligence Strategy cited climate change as contributing to increasing numbers of migrants, refugees, and internally displaced persons.[950] This will strain state capacity, further fracture societies, and could create breeding grounds for radicalization.[951] Similarly, the 2019 Worldwide Threat Assessment of the U.S. Intelligence Community concluded that climate change was "likely to fuel competition for resources, economic distress, and social discontent through 2019 and beyond," including migration of millions of people, which will burden global governance institutions, economies, and societies.[952]

Climate variability has increased conflict by fomenting greater resource competition, commodity price shocks, and food insecurity.[953] In 2019, U.S. Director of National Intelligence Dan Coats identified climate change as a threat to U.S. national security, noting that the nation "will probably have to manage the impact of global human security challenges" resulting from climate change.[954] A January 2019 Department of Defense report noted that climate effects are now a standard part of the military planning process, and some military-to-military engagements focus on climate-related activities.[955] These national security implications come at the same time that climate change is compromising U.S. military readiness, as discussed elsewhere in this report.

Climate change is also aggravating existing geopolitical tensions and strategic competition with Russia and China. This is particularly true in the Arctic, where the continued diminution of sea ice and snow coverage has the potential to open new shipping lanes and increase access to natural resources. These changes have worldwide repercussions and require U.S. efforts to reinforce the Arctic security environment with its allies. Russia's efforts to project strength in the region include forming the Northern Fleet Joint Strategic Command in 2014 and establishing new military bases along its Arctic coastline. China has increased its presence through economic outreach in Arctic states' strategic sectors and has declared itself a "Near Arctic State," a claim the United States does not recognize.

The multi-year drought in and around Syria beginning in 2006 exemplifies how climate extremes can intensify existing tensions and governance challenges, contributing to migration and conflict. The severe drought meant that many rural Syrians could no longer support themselves and led to the massive migration of rural residents into the country's major cities.[956] This influx came on top of the presence of existing Iraqi refugees, which together effectively overwhelmed local institutions, exacerbating instability and conflict.[957]

Recent major disasters show how climate-driven extreme weather abroad can impact U.S. humanitarian assistance. For example, in 2013, Typhoon Haiyan led to widespread destruction across the Philippines and the internal displacement of more than 4 million people. To assist in the aftermath, 13,400 U.S. military personnel were committed to the relief effort, and USAID separately provided approximately $100 million in immediate relief aid.[958] In 2019, back-to-back cyclones devastated Mozambique and neighboring countries. USAID responded with $120 million in immediate aid and relief funding, and many USAID programs in the area were reoriented to address long-term recovery.[959]

In a January 2020 ruling (*Kiribati v. New Zealand*), the United Nations Human Rights Committee recognized that individuals whose lives are imminently threatened by climate change may have a legal basis for refugee protection, further underscoring the global implications of climate-induced migration.[960] The ruling concluded that "without robust national and international efforts, the effects of climate change in receiving states may expose individuals to a violation of their rights."[961] This decision leaves opens the possibility of applying international asylum and refugee laws forbidding a receiving country from sending refugees back to a country in which they would be in danger.[962]

PROGRESS AND OPPORTUNITIES

The United States needs to rejoin the global leadership acting on climate

Tackling climate change will require a global effort. U.S. leadership is essential to meet the scale of the challenge and ensure that America does its part to protect this planet for future generations. The United States has historically been the largest contributor to global greenhouse gas emissions and continues to have one of the highest per capita levels of emissions. But getting our own energy policy right will not be sufficient. The United States currently accounts for 13 percent of annual global emissions, so international momentum is essential to prevent a climate crisis. While the Trump administration has eroded U.S. progress in combating this existential threat, the United States must again seize the mantle, join with other countries that are setting achievable net-zero goals, act on a national scale to address greenhouse gas emissions, and advance international leadership to meet this crisis.

Leading on climate will allow the United States to rethink how to approach global alliances, strengthen democracy at home, and offer a positive model of engagement for partners and allies. It will also present new opportunities to innovate technologically and develop avenues for exports and growth. Advancing progress on climate change can support global prosperity that contributes to greater international stability and stronger markets for U.S. goods.

Recommitting to the Paris Agreement

When the United States joined the landmark Paris Agreement, our leaders committed to cut the nation's net greenhouse gas emissions to between 26 and 28 percent below 2005 levels by 2025.[963] U.S. leadership played a key role in developing the Paris Agreement and inspiring other nations to act. It also fostered development of a final agreement that protected national sovereignty and economic prosperity, while gaining commitments from all countries.

Early in his administration, President Trump stated his intention to withdraw from the Paris Agreement, making the United States a single outlier among all nations and compromising worldwide ambition to mitigate greenhouse gas emissions.[964] President Trump also initiated a series of domestic policy rollbacks that have reversed U.S. progress in tackling greenhouse gas emissions and undermined America's ability to meet future targets.[965] U.S. climate leadership on the international stage is entirely absent. For example, the Trump administration has consistently abstained from climate change cooperation communiques and finance commitments promulgated at the G7 and G20. This pattern sets back global efforts to tackle climate change and marginalizes the U.S. private sector in global economic conversations.

The United States must recommit to the Paris Agreement and also submit a new Nationally Determined Contribution that articulates ambitious, science-based reductions for future years. By reengaging in international climate negotiations, the United States can press the international community to commit to similarly ambitious targets, as well as verifiable actions to achieve those targets.

Hydrogen fueling station in India

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Advancing climate progress through financing and investments

The United States should advance public and private support for the Green Climate Fund, an international climate fund that supports investment in low-cost climate pollution reductions, as well as climate adaptation. The Green Climate Fund supports projects that ultimately reduce U.S. climate risk, while bolstering U.S. global leadership and creating new markets for U.S. private sector investment and engagement. This fund—the outgrowth of efforts by President George H.W. Bush to establish the Global Environmental Facility in 1992 and by President George W. Bush to help create the Climate Investments Funds in 2008—has had a history of bipartisan support notwithstanding recent efforts by the Trump administration.

U.S. international finance policy should also advance climate mitigation and resilience. For example, the Export-Import Bank of the U.S. and International Development Finance Corporation must properly account for climate risks in their investments, weigh other social, environmental, and governance attributes, and evaluate each project through a climate impacts lens. These institutions can advance exports of made-in-America climate technology while expanding the use of low-carbon solutions. The United States should similarly press the World Bank and other global financial institutions to expand ongoing efforts to incorporate and properly account for climate risk.

Integrating climate into federal agency decision-making

The Obama administration made important progress in integrating climate change into key agency decision-making on matters related to foreign policy, national security, and humanitarian assistance. We must reestablish and build on these efforts, making climate a central, cross-agency priority in order to mitigate, respond to, and prepare for the political, economic, and security repercussions of climate change.

In particular, prior executive orders and presidential memorandums required agencies to create plans to address climate-related challenges to national security and develop and share information and tools on climate preparedness and resilience.[966,967] The Trump administration largely rescinded these common-sense efforts to prepare and strategize. The State Department is still considering rescinding a remaining executive order directing all agencies to integrate climate resilience into international development and investment.[968]

U.S. foreign policy and diplomacy should be marshalled to advance policy that supports climate solutions and takes the changed climate future into account. For example, the United States must take a clear-eyed view of the rapid changes occurring in the Arctic when building an enhanced, strategic approach to its participation in the Arctic Council.

Existing U.S. aid efforts should be appropriately mobilized and expanded to support climate solutions. By strengthening food security, bolstering other countries' efforts to enforce environmental laws, or advancing incentives and other programs to reduce deforestation, aid programs can support climate mitigation and adaptation in a way that strengthens foreign partners and U.S. interests. Again, the Trump administration has deprioritized or even obstructed these beneficial efforts, undermining national security. For example, the administration's hostility to the U.N. Sustainable Development Goals (SDGs) has contrasted with other countries.[969] China has recognized the SDGs as an opportunity to brand their international engagement as part of a global, cooperative effort.[970]

Joining the global effort to phase out HFCs

Hydrofluorocarbons (HFCs) are highly potent short-lived climate pollutants that can be found in refrigerators, air conditioning systems, foams, and some aerosols.[971] The increasing worldwide demand for refrigeration and air conditioning risks dramatically increasing emissions of this potent climate warmer,[972] but safer alternatives are available.[973] The United States and nearly two hundred nations agreed to the Kigali Amendment in 2016 to phase down use of these harmful compounds in

FIGHTING INTERNATIONAL DEFORESTATION

Across the globe, forests absorb 25 percent of carbon emissions.[987] When those forests are disturbed and destroyed, the stored carbon is released back into the air and a vital carbon capture and storage resource is no long viable.

Among the world's tropical forests, the Amazon is estimated to contain half of all global terrestrial carbon, but drought and man-made deforestation are threatening this essential carbon sink. Last year, from July to August, the rate of deforestation in the Brazilian Amazon reached approximately 13,000 square kilometers (nearly 5,020 square miles), which exceeded the total amount of deforestation in the last several years.[988] Every year, fires are set to prepare soil for crops and pastures, but these manmade fires sometimes uncontrollably burn beyond set perimeters and reach virgin forest. According to satellite data, the number of hotspots in the Legal Brazilian Amazon last year through early September was roughly 60 percent more than the prior year.[989] This deforestation has been attributed to a decline in the Brazilian government's enforcement of environmental laws and protections and increasing demand for large-scale agriculture, cattle ranching, and logging.[990]

As the world's largest tropical forest and a globally significant carbon sink burns, we are losing a vital tool in the fight against climate change. Leaders from countries around the world, including the United States, offered aid to combat the fires, while others suspended aid and threatened trade restrictions in an effort to motivate Brazilian leaders to take action in fighting the fires.[991] However, the Amazon is not alone in its importance to global climate solutions, and international aid and cooperative partnerships are critical to deterring further deforestation in many countries. The United States needs to lead by example by using financing and diplomacy to protect forests abroad, while working with stakeholders to advance protections for our own old growth forests.

cooling and manufacturing, a step that could avoid as much as 0.5 degrees Celsius of global warming by 2100.[974]

Bangui, Philippines

However, the Trump administration has yet to submit the Kigali Amendment to the Senate for advice and consent, notwithstanding strong bipartisan Senate support and backing from a broad constituency of stakeholders, including major American manufacturers.[975] Without ratifying the Kigali Amendment, the United States could lose out on billions of dollars' worth of exports and tens of thousands of jobs, according to a study sponsored by the air conditioning, heating, and commercial refrigeration trade association.[976]

The United States must move forward on transitioning to safer, effective alternative refrigerants, ratifying the Kigali Amendment, and meeting the terms of the agreement. This transition is an opportunity to create domestic manufacturing jobs, expand exports, and advance American industrial innovation. Our inaction in this space risks us ceding industry leadership to foreign competitors.

Tackling emissions from international transportation

Greenhouse gas emissions from the airline sector have increased rapidly in recent years, a trend projected to continue over the next several decades,[977,978] although the COVID-19 crisis has injected new uncertainty. In August 2016, EPA issued a finding that aviation greenhouse gas emissions endanger human health and welfare, and in July 2020 the agency released a proposed rule that would adopt aviation emission standards consistent with those of the International Civil Aviation Administration (ICAO).[979,980] If the United States does not follow through on implementing ICAO emissions and fuel efficiency standards, we risk divergence between U.S. airline operators and manufacturers and the international aviation industry that would dampen U.S. manufacturing and export opportunities.

The United States must commit to tackling aviation sector emissions, in partnership with other countries and consistent with the objective of achieving global net-zero greenhouse gas emissions across all sectors by 2050. This will require robust U.S. leadership to realize sufficient action internationally, bolster investment in research and development, and increase policy and technology innovation. A major part of these activities should be achieving greater efficiency and use of advanced fuels, with at least 50 percent lower greenhouse gas emissions on a lifecycle basis. The United States must also work in partnership with the International Maritime Organization to develop goals consistent with the objective of achieving net-zero greenhouse gas emissions across all sectors by 2050.[981]

Advancing research and development

The challenges of climate change present extensive opportunities for investment in research and development in low- and zero-carbon solutions, as well as creative public policy innovations. Increased R&D funding is an efficient investment in climate progress because of its positive externalities. Research and development efforts also open up possibilities for international collaboration, rapid spread of technological innovations from developed to developing nations, and reassertion of U.S. leadership and strengthening of alliances. The International Energy Agency recently underscored the importance of global clean energy research and development investment in light of the current economic crisis—highlighting the significant role that such investments can play in recovery and long-term economic health, but also the risk that such investments may be stymied by COVID-related disruptions as well as increasing demands on public budgets.[982]

Leading on Earth observations

The United States must reinvest domestically and work in partnership with allies to strengthen the global climate monitoring system for greenhouse gas emissions and climate impacts. As the United States invests in greater space capabilities, expanded earth observation should be an important component.

Earth observation efforts should include improving the global warning system for emerging climate challenges. Existing partnerships include the extreme weather monitoring supported by the SERVIR joint venture between NASA and USAID, the result of a collaborative development effort with numerous partners,[983] and the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM), which supports food security by supplying information on agricultural conditions.[984] As with investment in research and development, investing in earth observations will set the stage for more targeted efforts and international collaboration.

With wide-area observation capability and extensive data collection, earth observation satellites can provide the world with a much better understanding of the effects of climate change. For example, the Committee on Earth Observation Satellites notes that their satellites have "provided unambiguous evidence of non-uniform sea-level rise in open oceans and have proven to be the most accurate and objective way to detect this rise in sea level."[985] These observations are the foundation of opportunities for international collaboration, technology spillover, and novel data interpretation.

These Earth observations, when paired with appropriate on-the-ground monitoring and social and economic data systems, are essential in implementing and evaluating policy and international response options.

INNOVATION AND RD&D

America is at a critical juncture for clean energy and climate innovation. We must swiftly and substantially increase RD&D funding, financing, and tax incentives to drive the additional technological improvements and novel breakthroughs needed to combat the climate crisis.

The United States has a long history of leadership in innovation and research, development, and demonstration (RD&D). The federal government, higher education, and the private sector all have an essential role in RD&D advancing climate-related technologies. While many of the technologies we need to decarbonize our energy sector already exist, additional investments are needed to improve efficiencies, reduce costs, and solve outstanding issues. Full, economy-wide decarbonization will require even more substantial investments in innovation. A combination of federal funding, financing, and tax credits are needed to incentivize RD&D and scale deployment. Further, international agreements, federal regulations, and sector-specific standards can create the framework and targets that accelerate innovation and deployment. Over the years, regulations, emissions standards, and energy efficiency requirements have driven technological development in everything from cars, to power sector technologies, to household appliances. While this chapter focuses on federal RD&D in a few key sectors, and the necessity of expanding and improving funding and incentives, a wide array of policy tools and partnerships are required to galvanize and promote the full breadth of American climate innovation.

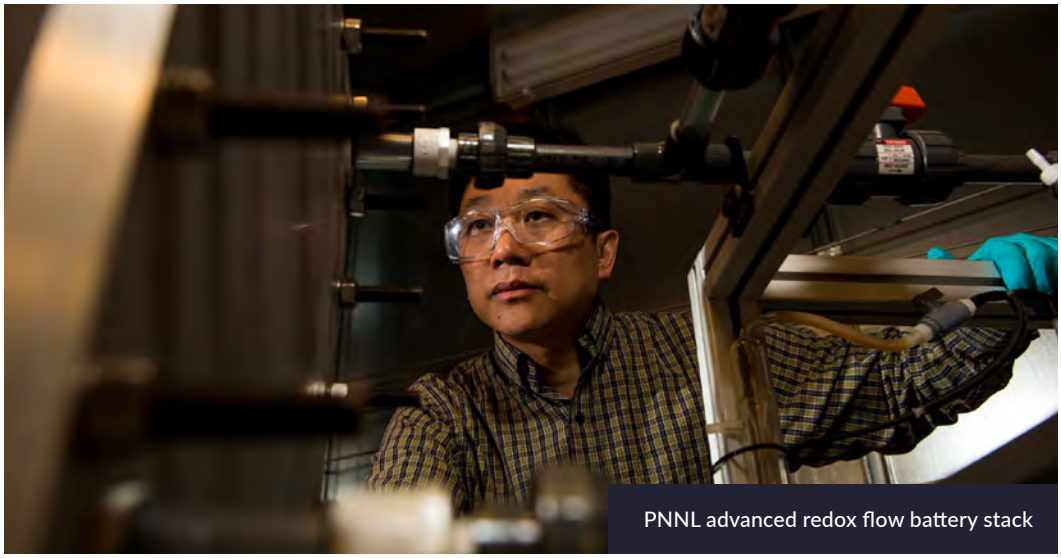
Past federal investments in innovation and RD&D have played a critical role in attaining the nation's current technological capabilities. Past U.S. investments also present examples of the type of coordinated initiatives necessary to build a stronger and more competitive clean energy economy today. For example, the energy crises of the 1970s led to the expansion of federal government R&D to include renewable energy and energy efficiency (and the rise of directional drilling and hydraulic fracturing). Department of Energy (DOE) funding for energy technologies rose in the 1970s to a combined peak in fiscal year 1979 of about $9 billion,[i] after which funding steadily decreased to about $2.1 billion per year during the late 1990s.[992] More recently, the American Recovery and Reinvestment Act of 2009 (ARRA)

i All figures in this paragraph are 2018 constant dollars.

provided an opportunity to inject $13.7 billion of new energy funding. ARRA supported clean energy and energy efficiency projects across the country and played a vital role in fueling innovation, especially by funding the cutting-edge Advanced Research Projects Agency–Energy (ARPA-E). In fiscal year 2020, DOE R&D funding is $5.3 billion.

The United States is now at another critical juncture for investing, financing, and incentivizing RD&D and deployment of technologies spanning clean energy and energy efficiency, sector-specific technologies and processes, and carbon removal technologies. The longer it takes to develop and deploy innovative climate technologies, the more aggressive—and potentially disruptive and costly—policy changes will need to be in the future to meet emissions reduction goals. Delayed investment in the transition also increases the likelihood of disorderly sector transitions that create or exacerbate inequities.

Progress in clean energy generation, storage, and grid modernization and efficiency are key facets of energy sector innovation. RD&D in these areas is increasing capacity, efficiency, and storage, and decreasing costs and other barriers to more widespread adoption. There is also progress being made in harder-to-shift sectors like transportation and industry.



Andrea Starr | Pacific Northwest National Laboratory

PNNL advanced redox flow battery stack

Rapid decarbonization is critical, but carbon removal technologies are also needed to reach net-zero U.S. emissions on a timeline consistent with that necessary to avoid the worst global impacts of climate change and meet the global net-zero target by 2050. All pathways the Intergovernmental Panel on Climate Change analyzed in its report, *Global Warming of 1.5°C*, for limiting warming to that level include some form of carbon dioxide removal, whether through natural systems or technology.[993]

Federal funding fuels all stages of the innovation process, including research, development, demonstration, and deployment (and scale-up) of new technologies. Financing, such as federal loans and tax incentives, also helps drive investments. Additionally, federal grants and loans help support important partnerships with state, local, and Tribal governments, as well as public-private partnerships.

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"[W]e need every arrow in the quiver, especially because the regional solutions will be different in different parts of our country and different parts of the world. So, the full [R&D] portfolio is absolutely essential. [...] We need a decade of super-charged technology, policy, and business model innovation, and there is simply no time to waste."[1072]

— Dr. Ernest Moniz

Former Secretary of the U.S. Department of Energy, and president and CEO of Energy Futures Initiative Inc.

To meet the challenge of the climate crisis, we must increase funding and expand financing and incentives for RD&D for climate-related technologies. Specifically, Congress should:

- ✔ Establish a framework for a holistic national clean energy and climate innovation platform.
- ✔ Develop a systematic assessment of existing RD&D programs and projects related to climate and clean energy to identify programmatic and funding gaps and needs.
- ✔ Create a multi-agency and stakeholder innovation council to conduct the systematic assessment and help develop and guide the innovation platform.
- ✔ Provide consistent and substantially greater federal funding at all stages of the innovation process, including basic and applied research, development, demonstration, and deployment.
- ✔ Expand and improve financing, such as federal loans, and tax incentives to help drive investments.

The transformational power of R&D, and its concrete benefits, are exemplified by significant cost reductions in recent years for solar and wind generation and batteries. However, whether it is additional advancements in energy storage, decarbonizing carbon-intensive industrial processes, scaling up negative-emissions technologies, or developing novel technologies, there remains a clear and continuing need for innovation and RD&D to spur breakthroughs in technologies and processes to combat climate change.

RISKS OF INACTION

Delaying or underinvesting in innovation has escalating consequences

Acting now to ease the transition

The United States has a responsibility to act on climate, especially in light of our nation's historical contributions to global emissions; while China is currently the largest source of carbon dioxide emissions, the U.S. is the largest cumulative emitter.[994] Increasing federal funding now, providing consistent funding, and sending clear policy signals are important ways to drive development. They are also necessary to help bridge the costs and often lengthy timeframe associated with the innovation process. This transition will help us grow the U.S. economy in new sectors and create good jobs.

© Los Alamos National Laboratory

LANL scientists teach short course on fuel cells

However, if we do not take significant steps now towards reaching net-zero emissions, the nation will have to make steeper reductions in the future. The more condensed the time period, the more drastic the response will need to be, and therefore, the more significant the economic disruption and changes to existing ways of life. Increasing investments in innovation now will make climate-related technologies cheaper for consumers and the economy in the long term. Further, accelerating development now will lead to new technological breakthroughs that could help make the transition to deeper decarbonization less difficult.

Mitigating inequities

If the United States does not sufficiently invest in both RD&D and broader energy and technology transitions in a timely manner, we risk leaving certain communities behind. Investment in technologies and processes must be paired with broader investments in these transitions—for example, development of a stronger pipeline for high-quality, good-paying jobs; and accessible and affordable retraining opportunities for employees, particularly underemployed, unemployed, or dislocated workers.

Institutions of higher education and registered apprenticeship programs are key partners in bridging this gap. The Innovation and Commercialization for a Regional Energy Workforce (I-CREW) program, sponsored by New Mexico State University and funded in part by the U.S. Economic Development Administration, is an example of the type of program that can blend clean energy integration and commercialization with workforce development and retention. Improving access to high quality science, technology, engineering, and math (STEM) education in schools in underserved communities also fosters opportunities for new generations of innovators. In addition, infrastructure investments and development necessary or complementary to climate-related RD&D and deployment, ranging from smart grids to broadband, public transit, and improved waste management, should be implemented in ways that include rural and environmental justice communities.

Protecting U.S. competitiveness in the global economy

Courtesy of Pacific Northwest National Laboratory

The United States was the largest global investor in R&D writ large as of 2018.[995] However, U.S. investments in research have not kept up with economic growth. The ratio of investments in R&D relative to GDP now lags behind major trading partners like Germany, Japan, South Korea, and Taiwan.[996] China is now close to surpassing the United States in total dollars spent on research. In addition, while U.S. investment in R&D declined, China's R&D intensity tripled between 1995 and 2019 and continues to grow at a faster rate than that of the United States. Our country has historically devoted substantial funding to energy R&D specifically. However, between 2015 and 2017, we fell from 13th to 14th place globally in terms of public energy R&D spending relative to GDP.[997] The U.S. government also utilizes a smaller portion of its research budget for energy compared to most other developed economies. Again, these trends stand in contrast to China, which has continued to grow its lead in public energy RD&D expenditures as a share of GDP. China was the world's largest market for energy investment in 2018, due to its significant public spending, government subsidies, and other supportive policies.

PROGRESS AND OPPORTUNITIES

The United States has a critical opportunity to maintain and strengthen its global leadership in innovation. This requires a substantial increase in RD&D funding, paired with more systematic cohesion in federal innovation priorities and efforts. A similar assessment, improvement, and expansion is merited for federal loans and tax incentives for clean energy and energy efficiency.

Federal policy must support robust innovation for clean energy, storage, and the grid

This section provides a sense of the range of current RD&D in clean energy, storage, and grid modernization, with priorities for further research and select examples of other opportunities. Congress has led the way in funding RD&D during the Trump administration, particularly because the President's budget requests have called for slashing funding for DOE's Office of Energy Efficiency and Renewable Energy and eliminating the ARPA-E. These are two of the main federal entities conducting clean energy applied research. Looking forward, our overarching federal investment priorities must include RD&D across clean energy sources; driving down the already competitive costs of clean power to consumers; 'greening' the production of hydrogen; lowering costs and increasing capacity and flexibility of energy storage; and modernizing the grid.

Courtesy of Sandia National Laboratories

Wind generation became the country's largest source of renewable power in 2019.[998] Federal RD&D priorities should include decreasing the initial cost of equipment, increasing turbine efficiency, and enabling more flexible siting, such as for high-altitude wind or more condensed turbine configurations. Offshore wind is another area of significant potential growth; the technical potential of the United States' offshore wind resource is estimated at more than 2,000

gigawatts, nearly twice the country's current electrical use.[999,1000] Advanced technologies like floating foundations also merit RD&D. More broadly, a group of U.S. and European researchers, including from U.S. National Laboratories, outlined three 'grand challenges' meriting research: (1) improved understanding of atmospheric flow in the key zone the plant operates; (2) materials and systems of individual turbines; and (3) optimized management of fleets of plants functioning synergistically within the electric grid.[1001] DOE selected 13 projects in October 2019 to receive funding, including for rural generation, offshore technology demonstration projects, and demonstration of cost-effective technology for taller towers that can overcome transportation constraints.[1002] Sandia National Laboratories is currently conducting R&D on a blade design that could allow turbines to be placed closer together, due to a faster dissipating wake, which could make both siting and scale-up of wind projects easier.[1003] This is useful for land-based wind, where space in optimal areas can be a constraint. Another key area of R&D is increasing coordination across plants, such as through demonstrating and deploying "grid-forming" controls that enable wind (or solar) equipment to form voltage and frequency levels. This and other efforts to increase synergies across resources will become increasingly important as the deployment of wind and other types of renewable energy increases. A few other main innovation opportunities that should receive greater funding include hybrid wind and solar facilities, smaller-scale distributed wind (or wind and solar) generation, and RD&D and deployment of wind facilities with storage.

Hydropower is the second-largest source of renewable power in the United States. It plays a key role in helping stabilize the power grid, as it is less variable than most renewables and pumped-storage hydropower can function as utility-scale grid storage. Broad R&D priorities include upgrading existing hydropower and developing new technologies for smaller, low-impact hydropower. In October 2019, DOE announced funding selections for hydropower projects across several areas of interest. These include developing a standardized way to calculate hydropower resources' flexibility benefits; assessing operational strategies to increase flexibility; and designing and producing new standardized technologies for low-head hydropower.[1004] RD&D can also increase hydropower flexibility by advancing different types of passive and active control technologies to mitigate flow instabilities, as well as emerging magneto-rheological control techniques.[1005]

Marine and hydrokinetic energy are emerging technologies that merit increased RD&D investment. Marine projects were also included in DOE's funding selections in October 2019, including projects to improve the performance of wave energy converters in preparation for open-water testing, and to upgrade infrastructure at existing National Marine Renewable Energy Centers. In March 2020, DOE also announced funding for marine energy foundational R&D, the creation of an Atlantic Marine Energy Center, solicitation of a foundational research network facilitator, and funding for mobile test vessels.[1006] As current RD&D is primarily in the design through demonstration project phases, there are opportunities for innovation at various stages of the development process.

Solar energy is the third-largest source of renewable power in the United States. R&D priorities should include decreasing production and materials costs, advancing commercial-scale installations, developing more efficient materials and systems that

Courtesy of Sandia National Laboratories

Sandia's Photovoltaic Systems Evaluation Laboratory

perform better in varying conditions, and effective integration of solar and storage. Currently, there is a gap in both cell efficiency and cost between most current silicon-based solar cells and multijunction cells that combine different materials. Design, construction, and materials all factor into efficiency, and driving down costs will be a key factor in expanding usage of more efficient cells beyond the lab. In February 2020, DOE announced funds for projects related to photovoltaics (PV) hardware research, hardware manufacturing, integrated thermal energy storage, evolution and diffusion studies, systems integration and resiliency, solar and agriculture, machine learning for solar, and small innovative projects related to both PV and concentrated solar power.[1007] A cohort selected by DOE is working on rural projects related to siting and financing, analyzing deployment value streams of electric co-op members, best practices for co-op deployment of solar-plus-storage, and analysis of adding battery storage to manage solar interconnection costs.[1008] Another cohort is working on commercial-scale projects related to community solar-plus-storage, an urban energy resiliency hub, and a regional framework for integrating resilience into cost-benefit analyses of solar-plus-storage. In 2019, Sandia National Laboratories and an international research group launched a collaborative effort to study PV performance and reliability at field sites around the world, in order to support optimization of PV systems for different operating environments.[1009] Other opportunities include development of systems to generate ultra-high heat from sunlight for industrial use, incorporation of micro-solar cells in textiles, and advanced solar distillation.

Energy production from biomass includes biodiesel, energy crops, landfill gas and biogas, municipal solid waste, algae, and wood waste. U.S. investments in bioenergy R&D should prioritize advancing ways to efficiently produce bioenergy from agricultural, municipal, or industrial waste and development of renewable hydrocarbon biofuels. These forms of bioenergy offer particular promise for decreasing emissions in harder-to-shift sectors. It is also important that biofuels be produced sustainably. The Oak Ridge National Laboratory's

Center for Bioenergy Innovation has identified three overarching research targets: (1) sustainable biomass feedstock crops using plant genomics; (2) advanced processes to convert plants into specialty biofuels; and (3) valuable bioproducts, such as chemical feedstocks made from lignin residue from bioprocessing.[1010] In 2019, ARPA-E announced funding to develop technologies to quantify feedstock-related emissions at the field level.[1011] DOE also announced R&D funding for projects related to improving algae yield, enhancing conversion efficiency, lowering costs of smaller wet waste systems, and using systems research to improve performance and lower costs of hydrocarbon biofuels.[1012] Renewable hydrocarbon biofuels, or 'drop-in' fuels, present opportunities to replace petroleum in existing pipelines, refineries, and engines; this field particularly merits increased R&D funding.

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A U.S. Department of Energy geothermal test site (Naval Air Station Fallon in Nevada)

Geothermal energy is not impacted by seasonal factors and provides a constant source of power. Broad R&D goals include identifying ways to safely and sustainably leverage geothermal power and accelerate demonstration of enhanced geothermal systems. Enhanced geothermal systems utilize a water-filled fracture and reservoir network to create suitable conditions for geothermal development in areas where it would not otherwise be feasible. In its 2019 *GeoVision* analysis, DOE outlined opportunities for increasing geothermal power generation.[1013] A few of the areas of R&D noted are enhancing detection of subsurface signals, improving geothermal drilling and wellbore integrity, and increasing geothermal energy resource recovery. The report also noted a pronounced economic potential for geothermal district-heating systems in the Northeast corridor of the United States. In February 2020, DOE announced funding to advance enhanced geothermal systems technologies and techniques,[1014] to explore hidden geothermal systems in the Basin and Range region, and for bi-directional energy storage using low-temperature geothermal applications.[1015] DOE is also helping fund a new Geothermal Entrepreneurship Organization at the Cockrell School of Engineering at the University of Texas at Austin, to serve as a national hub for engineers, researchers, and entrepreneurs.[1016] Additional geothermal RD&D opportunities relate to enhanced geothermal methods, sustainability, and use of geothermal energy for grid management, desalination, or production of critical minerals.

Nuclear energy currently plays an important role in providing reliable zero-carbon power to the grid. While a U.S. Energy Information Administration reference case projects that nuclear generation could decrease by 7 percent between 2019 and 2050,[1017] next-generation nuclear energy could continue to provide a baseload clean power source. In addition to funding nuclear energy research, Congress should pursue a consent-based process to address the nation's nuclear waste. Research priorities include advanced nuclear reactor R&D, including to improve safety of plant operations, improving the efficiency of the existing nuclear fleet, and nuclear R&D infrastructure modernization. There are various types of advanced reactors, some of which can be constructed as small modular reactors, which may offer a potential for lower capital costs and faster construction. Light water-cooled small modular reactors, high-temperature gas-cooled reactors, and sodium-cooled fast reactors are among the next-gen technologies.[1018,1019] The Idaho National Laboratory is collaborating with NuScale Power to build a light water small modular reactor, which could receive a final safety report from the U.S. Nuclear Regulatory Commission as early as September 2020[1020] and potentially begin operations in the mid-2020s. Nuclear R&D infrastructure is also an important area of innovation. DOE is leading a public-private partnership to build a Versatile Test Reactor with fast neutron testing capability, for accelerated testing of advanced nuclear materials, fuels, instrumentation, and sensors.[1021] The project is currently slated for completion by 2026.[1022]

Hydrogen has a variety of applications—for instance, in cars, homes, and for portable power—making it crucial to 'green' and scale hydrogen through increased RD&D funding. While hydrogen can be produced from diverse sources, most hydrogen is currently generated using natural gas. While hydrogen emits no carbon dioxide when used as fuel, producing it from natural gas releases greenhouse gases. Carbon capture, utilization, and storage (CCUS[ii])[1023] can be used during production to capture the carbon dioxide and store it long-term or use it to make valuable products. RD&D can advance the capacity of CCUS to help turn wasted carbon into products like cements, chemicals, or plastics. Developing hydrogen from renewable energy and driving down the cost of this green hydrogen is a priority, and will require substantial RD&D. Technology that uses grid-based electricity to split water into hydrogen and oxygen (electrolysis) should be scaled up, and RD&D must spur the use of electrolysis in industrial processes. Using renewables like solar and wind to produce green hydrogen through electrolysis should be a near-term RD&D focus. Innovation is also needed to advance other green hydrogen technologies using wind, solar, and biomass. Biomass pathways span the near- to long-term range and wind and solar pathways are in the mid- to long-term range, depending on the specific technology,[1024] with opportunities for innovation in each pathway. Green hydrogen is currently more expensive than natural gas-derived hydrogen. Increased and targeted R&D is needed to make it more cost-competitive, including by lowering fuel cell and electrolyzer unit costs, while other R&D needs include scaling electrolyzer systems and retrofitting turbines for green hydrogen.

ii Carbon utilization: the manufacture of valuable products from a gaseous carbon waste feedstock (carbon dioxide or methane) that results in a net reduction of greenhouse gases emitted to the atmosphere.

Energy storage supports grid reliability and creates flexibility by storing renewable energy and deploying it during periods of lower output or peak demand. We must invest in R&D to develop longer-term storage, lower costs, and develop integrated renewables and storage. The United States had a 93 percent increase in the amount of storage deployed in Q3 2019 compared to Q3 2018, and DOE's Global Energy Storage Database includes nearly 700 U.S. energy storage projects in various stages of development.[1025] In January, 2020, DOE announced the Energy Storage Grand Challenge to spur U.S. leadership in usage, exports, and a robust domestic supply chain by 2030.[1026] Most energy storage technologies in use are for minutes or hours. Flexible multi-hour systems, long-term storage (such as 10-100 hours), and multi-month storage are RD&D priorities.

One type of storage utilizes a stored medium. Pumped-storage hydropower represents approximately 95 percent of U.S. utility-scale storage,[1027] and is currently the most prevalent example of a stored medium system. More RD&D is needed to examine and advance the capacity of other stored medium technologies to meet long-term or seasonal needs, such as compressed air, cryogenic energy, thermal energy, and green hydrogen. Gravity-based energy storage is an emerging technology that may also offer promise as longer-term storage. The most prominent versions use renewables-powered electric cranes or rigs to raise tons of concrete bricks when power output is high and release them when power is needed, functioning somewhat like pumped hydropower. Flywheels, on the other hand, are used for a large amount of power for a short time period; main research areas in that space include materials and design R&D to increase rotor speed. Another category of storage includes batteries, electrochemical capacitors, and superconducting magnetic energy storage. A few R&D priorities for these types of storage are identifying more sustainable and available materials for lithium-ion batteries, use of advanced electrolytes for flow batteries, and improvements to high-voltage capacitors. Argonne National Laboratory is also examining ways to utilize machine learning to help identify possible battery electrolyte

ACTION ON LONG-DURATION ENERGY STORAGE

Long-duration, grid-scale energy storage will be a crucial component in decarbonizing the electric sector. It will allow us to store clean, renewable energy when resources are plentiful, and use that stored energy when we need it. Companies like Form Energy are leading development of ultra-low-cost, long-duration energy storage for the grid. In May 2020, Form Energy announced plans for a joint project with Minnesota-based utility Great River Energy to deploy a 1-MW, grid-connected battery storage system capable of delivering full power continuously for 150 hours.[1073] This is far longer than the two- to four-hour usage period typical of the utility-scale lithium-ion batteries being deployed today. Such advances will mean battery storage can become an essential component of grid stability, rather than only relying on traditional sources like dispatchable thermal- or hydro-generation resources. Form's aqueous air battery system is based on abundant materials and offers a clear path to transformational low-cost, long-duration energy storage.

candidates. Accelerating integration of clean energy generation and storage is another major RD&D priority. One example of integrated green hydrogen and storage comes from the National Renewable Energy Laboratory, where engineers patented a method and tower configuration for storing gas in a steel wind turbine tower.[1028] Developing long-term and seasonal storage, and making it cost-effective, will be an essential part of scaling renewable energy to the level needed to meet emission reduction targets. That makes it a high priority for significantly increased RD&D funding, including funding aimed at breakthrough technologies.

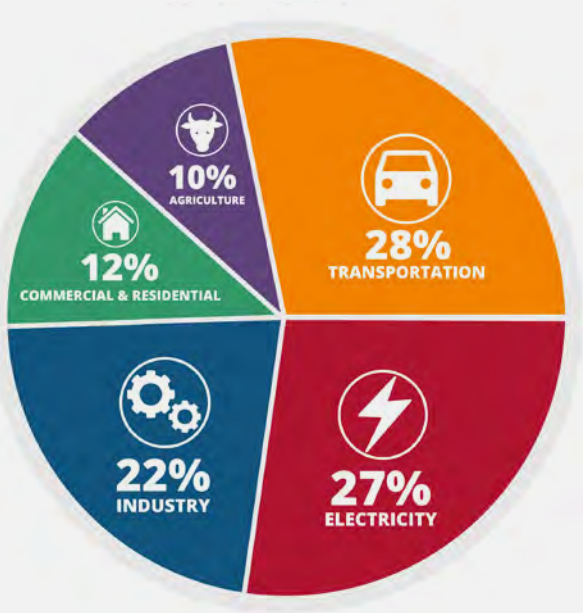
The U.S. electrical grid is aging, and the nation's power needs continue to grow, making grid modernization a necessity. Investments in updating the grid should prioritize R&D that supports integration of large- and small-scale renewable energy projects and increases efficiency. Between 2014 and 2018, annual electricity transmission and distribution losses averaged about 5 percent of the electricity transmitted and distributed annually.[1029] Smart Grid technologies enhance communication, monitoring, and control systems across the grid to improve reliability, flexibility, and efficiency. Examples of innovative Smart Grid tools in R&D include phasor measurement units that monitor and measure grid reliability over mere microseconds; smart meters that communicate with the grid in close to real-time; relays and feeder switches that automatically respond to faults or problems; and advanced grid analysis software. In 2019, Los Alamos National Laboratory developed the Severe Contingency Solver for Electric Power Transmission, open-source software to predict how damage from extreme weather events will impact utilities' power delivery.[1030] In addition, ARPA-E is holding a multi-round Grid Optimization Competition to spur development of software management solutions for challenging grid situations, which runs from 2018 through 2021.[1031]

Other necessary grid modernization R&D pertains to advanced power electronics that will optimize delivery and resilience; adaptive networks to improve system responses; and machine learning models. DOE's Buildings-to-Grid program advances two-way interaction between aggregated buildings and the grid, enabling buildings to act as a type of storage—and possibly later generate compensation for the grid benefits they provide. The Pacific Northwest National Laboratory has been leading R&D on grid-interactive buildings. The virtual power plant model consists of a network of distributed energy resources, such as networked solar-and-storage, managed through cloud-based controls. This type of system can provide various grid services. Stationary fuel cells can also be connected to the grid and used for supplemental or backup power (or used as a stand-alone generator or for combined heat and power), increasing reliability. Another area of opportunity is microgrid R&D to improve grid reliability and integration of renewables. Additionally, expanding transmission holds longer-term promise for helping address seasonal variability, by enabling power generated in an area experiencing higher output to be conveyed to areas with temporarily lower output.

Solutions are emerging for harder-to-shift sectors, but more work is needed

Some of the main pathways to transition the transportation, industrial, buildings, and agriculture sectors involve finding ways to electrify processes or components, use cleaner fuels or materials, or increase energy efficiency. While this section focuses more on decarbonization, innovation is also needed related to minerals and materials used in these sectors and their supply chains, to reduce environmental pollution and risks of over-dependence on other countries.

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2018



Source: U.S. Environmental Protection Agency, Sources of Greenhouse Gas Emissions

The transportation sector had the largest share of greenhouse gas emissions in 2018, at about 28 percent of total U.S. greenhouse gas emissions.[1032] Over half of these emissions are from passenger cars and light-duty trucks. While electric and hybrid vehicles are increasingly cost-competitive and hydrogen fuel cell vehicles are also in operation, R&D can further reduce costs, expand distance ranges, and increase sustainability. One of the main priorities of the lithium-ion battery recycling R&D center established at Argonne National Laboratory in 2019 is developing a new recycling process that reuses components directly, reducing the cost of electric vehicle batteries. Research in advanced electric charging is also necessary to reduce charging time and develop wireless charging. In January, 2020, DOE announced funding for R&D in advanced batteries, alternative fuels demonstrations, and innovative concepts to scale up hydrogen production and use.[1033] R&D to lower capital costs and increase ranges of clean public transportation is a necessary complement.

Aviation, freight, and shipping are additional areas for further innovation. Promising propulsion for planes includes renewable drop-in fuels, hydrogen fuel cells, and battery-electric engines. Biofuels can be made from industrial process waste gases, reusing carbon. For hydrogen fuel cells, R&D is needed to determine how to store more hydrogen for long flights, while a priority for battery-electric R&D is increasing energy storage while decreasing weight. In 2019, DOE announced funding for two programs to develop low-cost electric plane engines and powertrain systems.[1034] In addition, one regional airline in Massachusetts has ordered a fleet of small electric planes that could be in operation as early as 2023.[1035] R&D to achieve more aerodynamic bodies or wings or lighter materials can also help reduce emissions. Freight, which encompasses road, rail, air, and ocean, can span long distances. Medium and heavy-duty battery and fuel cell electric trucks and vans present an opportunity for near-term progress. A few manufacturers have fleets in operation, ranging in size from smaller pilot programs to over 100 battery-electric trucks, with a handful of other manufacturers ramping up production within the next year or two.

Electrification is a key decarbonization pathway for rail, with both battery-electric and hydrogen fuel cells meriting R&D. One of the largest U.S. freight rail networks announced in 2019 that it would soon begin testing a battery-electric high horsepower road locomotive (which moves freight trains).[1036] In addition to technological research, particularly around batteries, another necessary area of R&D for transitioning freight rail is targeting ways to lower upfront costs. Of relevance for shipping, the United Nations International Maritime Organization adopted a decarbonization strategy in 2018 that calls for reducing total annual greenhouse gas emissions by at least 50 percent by 2050 compared to 2008.[1037] A lignin and ethanol blend and cooking oil are two of the biofuels in R&D for use in shipping. Hydrogen and ammonia are considered promising alternatives, but RD&D is needed to advance green production and address the special storage considerations for these fuels. One manufacturer plans to deliver its first ammonia engine in 2024. Efficiency is another aspect of emissions-reducing RD&D in shipping, and ranges from rotor sails, to paints that improve glide, and "flapping foil" propellers.

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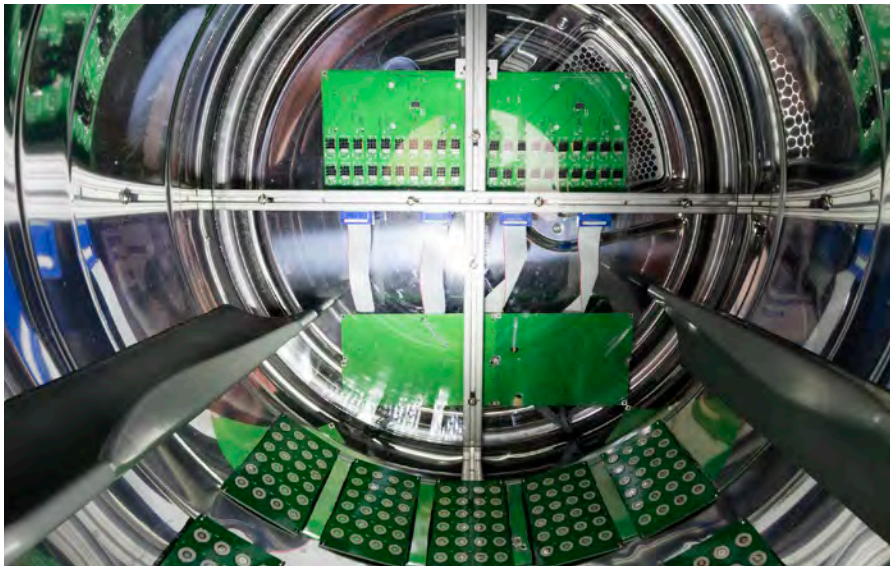
The industrial sector produces direct carbon emissions onsite, as well as indirect emissions that come from offsite generation of electricity to power industrial facilities. In 2018, direct industrial greenhouse gas emissions were 22 percent of total U.S. greenhouse gases, making industry the third-largest emitter after transportation and electricity. However, if indirect emissions are included, the sector's share rises to 29 percent, making it the largest contributor.[1038] Manufacturing processes for certain building materials, chemicals, polymers, and other products are ripe for future integration with CCUS, with the captured carbon then used in industrial processes. RD&D in this area is critical to industrial decarbonization. Converting waste heat from industrial processes (such as

production of cement, glass, steel, or aluminum) to power is another method of utilization. R&D priorities include increasing conversion efficiency, developing ways to effectively convert low-grade heat, and reducing the cost and energy usage of producing component materials. Combined heat and power and waste heat to power technologies also utilize heat that would otherwise be wasted, and R&D can increase turbine efficiency, availability of smaller systems, and usage of a wider range of fuels. Green hydrogen and new forms of concentrated solar power are other promising technologies that can be used to generate industrial heat, as well as be converted to methane for use in industrial and chemical processes. There are also efforts underway to develop new forms of concentrated solar power to generate industrial heat. As the International Energy Agency notes, lower temperature heat from electric heat pumps could be used in certain processes in the food and beverage, pharmaceuticals, and textiles industries, with some applications in the pulp and paper and chemical industries as well.[1039] There are also various frontier electric technologies in different stages of development, including electrification of clinker production for cement using electromagnetic heating, hydrogen-based direct iron reduction for primary steel production, electro-technologies for process heat, and mechanical vapor recompression.[1040] As outlined in a recent *Applied Energy* study on technologies and policies to decarbonize global industry, changes to materials and techniques used to produce some of the most common building materials (cement, iron, and steel) and feedstocks and processes to produce chemicals are a key facet of supply-side technologies to decarbonize industry.[1041]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The commercial and residential building sector includes commercial businesses (except industrial and agriculture activities) and homes. In 2018, its direct greenhouse gas emissions represented approximately 12 percent of the U.S. total, making it the fourth-highest emitting sector.[1042] Direct emissions are primarily related to heating and cooking, management of wastewater and waste, and leaks from refrigerants. The building sector is also responsible for indirect emissions from the electricity used by businesses and homes. About 47 percent of energy consumed in buildings is electricity, followed by natural gas at 41 percent, and then other petroleum products, biomass, and district (multi-building) heating.[1043] Building processes are a significant portion of sector emissions, with heating making up the largest source of energy demand.[1044]

Electrification of heating (both space and water) and cooling, including using electric heat pumps, can be a feasible shift. As noted in a 2018 Lawrence Berkeley National Laboratory report, "In buildings, nearly 100 percent of energy use can be electrified with today's technologies."[1045] The study also identified a need for R&D to improve cold-weather

performance of heat pump technologies and lower costs, as well as regional research on the economic viability of electrification for different building types—thus accounting for different energy costs and climates. Other potential buildings process technologies include development of advanced building-scale thermal energy storage, hybrid thermal and battery storage systems, or networked ground source heat pumps. An important sector shift is taking place related to hydrofluorocarbons (HFCs), which have a high global warming potential. HFCs are used in cooling and refrigeration, aerosols, foam production, fire protection, and other industrial uses. Today, global markets are moving away from the use of HFCs because of the recent international Kigali Amendment to the Montreal Protocol. Fortunately, U.S. companies have a competitive advantage in HFC alternatives. Phasing down HFCs through policy can drive further innovation, reduce emissions, and support additional manufacturing jobs in the United States.

Energy efficiency spans building design and appliances alike, with 'smart' technology, grid-interactive technologies, machine learning, and advanced data analytics influencing both. Advanced controls and building management can be optimized based on real-time occupancy, among other factors. One example is a recent announcement of the first autonomous building sustainability system, which continuously studies energy consumption and automatically adjusts to optimal energy savings.[1046] Innovation in materials can also decrease carbon intensity or increase efficiency. Mass timber, such as cross-laminated timber (CLT), merits additional R&D as an alternative building material, including for larger commercial applications. In addition to wood sequestering carbon, when harvested sustainably, the manufacturing process for wood products can produce fewer carbon emissions than the manufacturing process for building materials like steel or concrete. A recent study from Columbia, Howard, and Peking Universities identified a bilayer paint coating that offers the high solar reflectiveness of a white or silver paint

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but enables buildings to be any color, and can stay as much as 3 to 15.6 degrees Celsius cooler in strong sunlight compared to commercial paint of the same hue.[1047] According to DOE, certain electrochromic window glass can reduce a building's energy consumption by up to 20 percent and reduce building HVAC costs by up to 30 percent.[1048]

The agricultural sector represented 10 percent of total U.S. greenhouse gas emissions in 2018.[1049] Historical agricultural R&D has helped increase crop and livestock productivity, which helps reduce conversion of agricultural land, a climate stressor. Research being conducted today can help reduce agricultural emissions and increase carbon sequestration. R&D is needed to achieve these goals and identify ways to improve mitigation and adaptation to the changing climate and risks like increased floods and droughts that come with it. Management of soils, such as use of certain fertilizers, drainage of organic soils, and irrigation techniques constitute the sector's largest nitrous oxide emissions. However, regenerative agriculture practices like no-till farming, use of cover crops, and nitrogen management can decrease emissions. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service worked with Colorado State University to develop the COMET-Farm online tool for farmers and ranchers to get estimates and evaluate options for reducing emissions and sequestering more carbon on their land.[1050] There are also R&D opportunities to increase carbon storage through crop engineering, such as by enhancing root systems. The Salk Institute for Biological Studies is examining ways to increase suberin, a naturally occurring carbon absorbing substance found in plant roots.[1051] A 2019 study by Salk and international researchers identified a specific gene that controls how roots grow, which researchers could potentially use to grow deeper roots and store carbon deeper in soil.[1052] The Agricultural Research Service and some land grant universities and companies are also conducting R&D in crop traits, microbes, and molecules to make plants more resilient and help protect them from inclement conditions or pests.

Methane produced by livestock accounts for the second-largest portion of agricultural emissions. Feed additives for livestock are one of the main areas of R&D in this space. The Foundation for Food and Agriculture Research (FFAR) has previously funded research on red seaweed as a feed additive for dairy cattle.[1053] USDA's National Institute of Food and Agriculture supported a 2019 study which found that adding a synthetic molecule to dairy cows' feed reduced their enteric methane emissions by about 25 percent,[1054] building upon the 2016 discovery of the molecule.[1055] Livestock manure management practices contribute to both nitrous oxide and methane emissions. R&D can increase the effectiveness of anaerobic digesters for livestock producers to manage manure and capture and utilize methane for energy. Agricultural wastes also offer promise for other applications, such as R&D around bioplastic. Farmers, ranchers, and rural communities are on the front lines of climate change. Robust agricultural R&D can help reduce carbon emissions while giving producers more resilient crops and new economic opportunities, like incentives for carbon sequestration. Both outcomes can help sustain rural businesses for future generations.

Carbon capture and removal technologies are an essential supplement to decarbonization

All pathways that limit global warming to 1.5°C by mid-century include some form of carbon dioxide removal, whether through technology or natural systems.[1056] While this section focuses on technological approaches, research on enhancing natural carbon dioxide removal is also merited. Carbon dioxide removal technologies can help accelerate emissions phasedowns, but must be paired with decarbonization—not mischaracterized as a way to continue 'business as usual.' CCUS and direct air capture (DAC), two of the most prominent types, are both ripe for additional innovation, though CCUS is more mature. CCUS captures carbon dioxide from stationary sources of emissions and transfers it to locations where it can be utilized or stored, while DAC removes carbon dioxide from the atmosphere and concentrates it, allowing it to then be utilized or stored as well. Both sets of technologies require infrastructure like pipelines and compressors.

CCUS technologies are an important tool in reducing emissions from harder-to-decarbonize sectors and technologies, such as certain industrial process emissions. RD&D priorities include expanding greener CCUS uses, lowering the cost of retrofitting existing plants, and increasing conversion efficiency of carbon dioxide to chemicals and other value-added products. The DOE Carbon Utilization program, much of whose applied research is carried out by the National Energy Technology Laboratory, focuses on R&D related to three main conversion pathways. These include carbon uptake (via algae), conversion into value-added products (synthetic fuels, plastics, chemicals), and mineralization (cements, aggregates, bicarbonates, associated inorganic chemicals).[1057] Carbon can also be stored underground in depleted oil and natural gas reservoirs, deep saline aquifer formations, or unmineable coal seams. There are 19 large-scale CCS facilities in operation globally, another four under construction, and 28 in various stages of development.[1058] In April 2020, DOE announced funding for engineering studies of carbon capture systems for industrial sources; testing advanced carbon capture materials or processes; and assessing commercial-scale geologic storage sites and the feasibility of capture or purification technologies for the sources.[1059] In addition, in November 2019, the Los Alamos National Laboratory won an R&D 100 Award for its SimCCS$^{2.0}$ open-source software, which can be used to design cost-effective pipeline networks linking carbon dioxide sources with sites where the carbon dioxide can be stored or utilized.[1060]

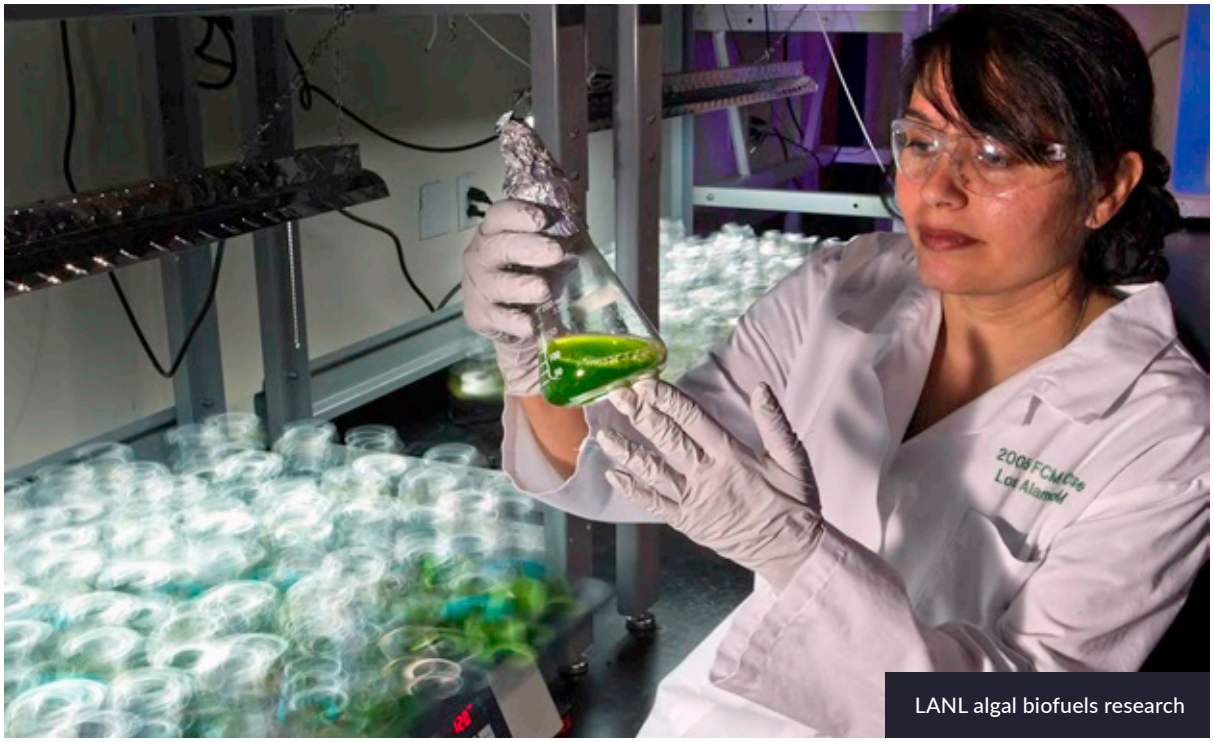
While DAC is still an emerging technology, it offers the significant benefit of removing both current and historical carbon dioxide emissions from the atmosphere, and is a useful supplement to decarbonization. Unlike CCUS, which relies on large point sources of carbon emissions, DAC can be sited near areas where carbon can be utilized or stored. DAC's versatility can help offset carbon emissions from sectors that are harder to decarbonize. The three primary categories of DAC are chemical, membrane, and cryogenic, with chemical garnering the most attention. DAC processes are energy intensive, increasing the importance of access to low-cost clean energy and process heat. As DAC has no fundamental physical limit for achieving carbon dioxide removal, limits to its scale are largely due to cost or location. Currently, there are several DAC companies across the world, though only a few plants. DAC has not historically been a focus area for DOE research.

However, in report language for the fiscal year 2020 appropriations bill, Congress directed DOE to invest at least $60 million in negative emissions technologies R&D, including no less than $35 million in DAC research.[1061] As noted in an Energy Futures Initiative report on carbon dioxide removal pathways, primary overarching objectives for DAC R&D include reducing costs and energy usage and improving performance and durability. Key elements of this R&D include: "(1) improved DAC materials, including sorbents, solvents, and membranes, (2) engineering development focused on technology performance and cost improvements, equipment manufacturing, and heat energy management, (3) integrated system scale-up and testing through pilot-plant stage, (4) cost, lifecycle, and environmental analysis, and (5) military applications."[1062]

Expanding funding, financing, and incentives for RD&D

The federal government must substantially increase and better target appropriations and grant funding, loans, and tax incentives to support clean energy and other climate-related RD&D and deployment. While this section focuses on federal funding, financing, and incentives, it is also crucial to note the need for greater investments in climate innovation by research institutions and corporations. These investments and incentives can also act as signals and help grow the market for climate-friendly technologies, products, and services, a critical and complementary goal. Market growth can also be advanced through modernizing federal and state procurement criteria and prioritization, as well as through federal, state, Tribal, and local climate policies. Non-governmental organizations, businesses, and consumers can help signal demand by incorporating a climate focus in their own spending.

Current federal funding for clean energy and energy efficiency innovation is substantial. However, our country is not on track to double our low-carbon research funding by fiscal year 2021, a goal that was agreed to as part of the Mission Innovation initiative created at the 2015 Paris Climate Summit.[1063] Meeting this goal would mean increasing clean energy RD&D funding from $6.4 billion in 2016 to $12.8 billion in 2021.[1064] While this amount can be an interim target, substantially greater funding by 2030 will play a pivotal role in unlocking the vast, and crucial, innovation potential of this decade. One think tank calls for increasing climate R&D funding to at least $20 billion per year by 2030, including $2 billion annually for ARPA-E and $50 to $100 billion over the next 10 years for high-impact demonstration projects.[1065] An organization founded by investors cites a recommendation of increasing clean energy innovation funding to $35 billion over 10 years.[1066] In addition, increased funding should be specifically directed towards helping technologies traverse the "valleys of death" between the stages of the innovation process (research, development, demonstration, and deployment). These valleys represent common points where technologies or companies may experience higher risk or lower funding, and can fail to reach the next stage of the process. More consistent funding is also important, as uncertainty or delays in funding affect project planning and budgeting for research and deployment, both within the federal government and by state, Tribal, and local governments and private sector partners.



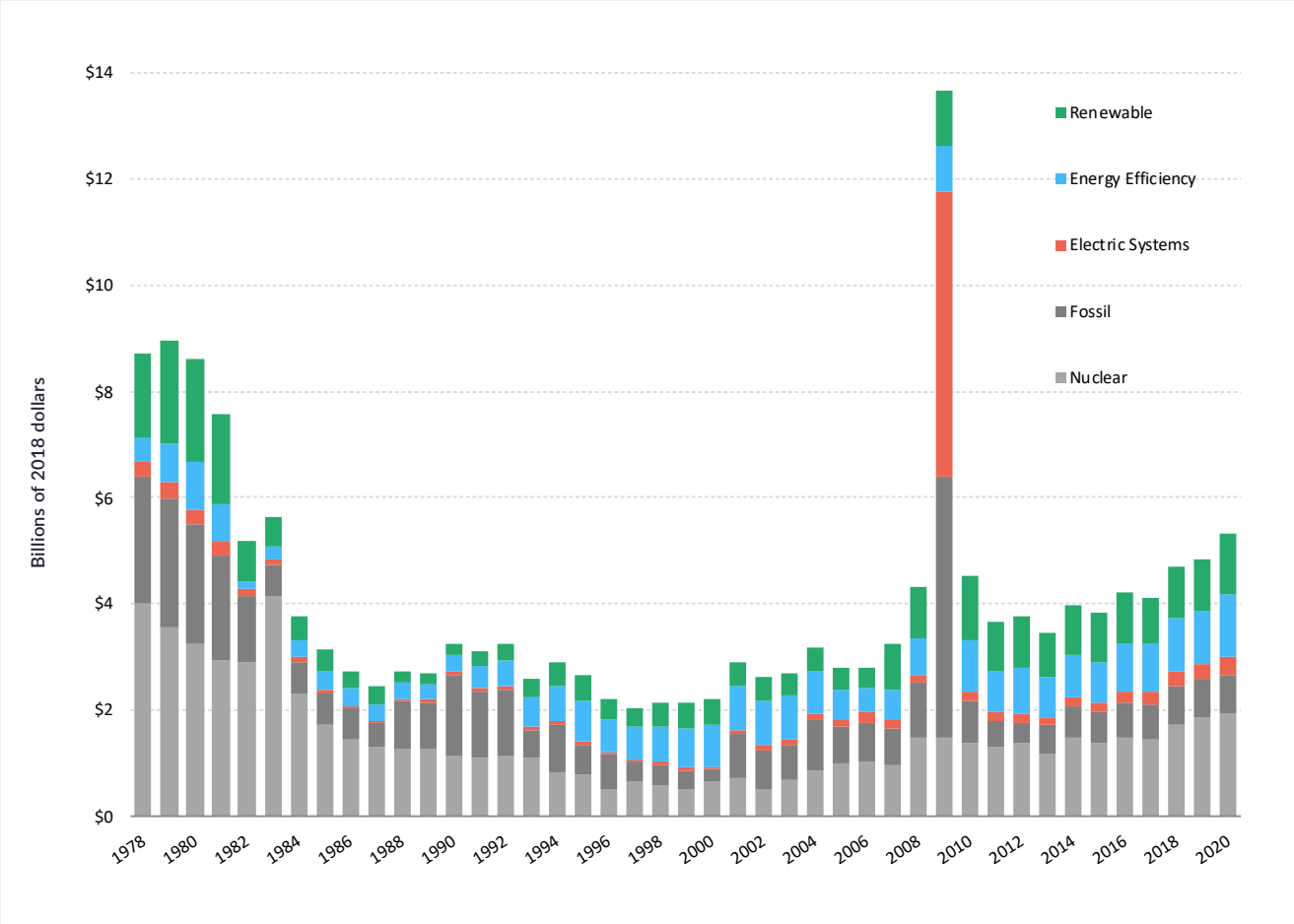
LANL algal biofuels research

The United States needs a holistic national clean energy and climate innovation platform spanning all relevant federal agencies and White House offices, with collaboration with the National Academies of Sciences, institutions of higher education, and other stakeholders. Congress should establish a framework for this type of government-wide climate innovation platform and an innovation council to guide it. A partial model can be seen in the U.S. Global Change Research Program (USGCRP), which coordinates federal research to improve assessments of, and responses to, the impacts of anthropogenic and natural global change. The 13 member agencies each develop and implement their own activities to further program goals, and USGCRP is tasked with providing an annual report on members' primary activities and topline spending figures. A new climate innovation council should conduct a holistic assessment of federal RD&D and innovation programs related to combating climate change. It should ascertain the full scale of additional funding needed, identify current gaps and any funds that could be redistributed to better recipients, provide a report, and incorporate its findings in future administrations' budget requests. A similar reassessment and expansion is also merited for federal climate and clean energy-related loan programs and tax incentives, including assessing which mechanisms and policies are best driving state, local, and Tribal innovation, or spurring the most private sector investment or consumer adoption.

DOE is the largest federal supporter of both fundamental and applied energy R&D. The primary DOE applied energy programs are within ARPA-E, the Office of Energy Efficiency and Renewable Energy, Office of Electricity, Office of Nuclear Energy, Office of Fossil Energy, and Office of Cybersecurity, Energy Security, and Emergency Response. The Office of Science serves an essential and complementary function as the primary entity supporting fundamental energy research. The 17 DOE National Laboratories, 10 of which are under the Office of Science, play a critical role in energy and innovation research. In addition to direct research, there are several key Department clean energy and efficiency grant programs.[1067]

Figure 1: Fiscal Year R&D Funding of DOE Energy Technologies

Courtesy of the Congressional Research Service



Source: DOE Budget Authority History Table by Appropriation, May 2007; DOE Congressional Budget Requests (several years); Deflator Source: The Budget for Fiscal Year 2021. Historical Tables. Table 10.1. Gross Domestic Product and Deflators Used in the Historical Tables, 1940-2025.

Notes: Column for FY2009 includes funding provided in the American Recovery and Reinvestment Act of 2009 (P.L. 111-5).

The Department of Defense (DoD) has a sizable budget for energy-related RD&D and has funded projects related to solar PV materials, battery storage, fuel cells, biofuels, and microgrids. The Defense Advanced Research Projects Agency (DARPA) has funded energy projects, and DoD both conducts research in its three laboratories and has ongoing project partnerships with DOE National Laboratories as well. Other agencies, including the Department of Transportation (DOT), USDA (as previously discussed), and the National Science Foundation (NSF), also fund clean energy RD&D. Other forms of climate R&D less focused on development of clean energy technologies are also critical. Integral research also occurs at the Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), and other USGCRP members.

To effectively combat the climate crisis, funding for clean energy and climate-related RD&D should be significantly increased across these agencies. ARPA-E, in particular, is an innovation leader: it supports projects at the earliest stages of development before most private funding, as well as projects entering the last valley of death before full deployment, and was built to provide grants in a more efficient and nimble way. It is also worth emphasizing climate-related technology development, and demonstration up to early deployment, across the DOE applied research programs. This spending would help projects traverse the demonstration and commercialization valleys of death, thereby bringing more clean technologies to market. In addition to appropriations, substantial increases in funding for these programs could also be provided through a clean energy, transportation, and infrastructure-focused economic growth and tax package.

Loans are another main way the federal government drives innovation. DOE's Loan Programs Office has up to $44 billion in available loan authority, including up to $24 billion for the Title XVII Innovative Energy Loan Guarantee Program, $18 billion for the Advanced Technology Vehicles Manufacturing Loan Program, and up to $2 billion for the Tribal Energy Loan Guarantee Program.[1068] At the end of fiscal year 2019, the Office had issued $36 billion in loans and loan guarantees and had 19 active Title XVII projects and one advanced technology vehicle manufacturing project. Since the office issued its first loan in 2009, the Title XVII program has reached a cumulative 31.2 million metric tons of carbon dioxide emissions avoided, with the advanced technology vehicles manufacturing program at 23.2 million metric tons.[1069] Title XVII is available for advanced fossil fuel, advanced nuclear, and renewable energy and efficient energy projects that avoid, reduce, or sequester greenhouse gases. The original program (Section 1703) was designed to help bridge the 'initial commercial deployment'[1070] funding gap, or commercialization valley of death, between demonstration and full deployment. However, a number of the loans issued have been through a temporary renewable energy deployment sub-program (Section 1705) created through ARRA. This subprogram, whose authorization expired at the end of fiscal year 2011, was more flexible in that funds were appropriated to cover projects' credit subsidy costs and the innovativeness requirement was relaxed somewhat. While Title XVII has garnered results, there are ways to improve its efficacy, and a number of proposals have been offered. Many cite a need for longer-term funding, as well as appropriating funds for part or all of credit subsidy costs, while others focus on flexibility. Codifying the ability of state-based lenders to partner with Tribes or businesses on projects could spur additional collaboratively-funded projects. The requirement that a project utilize 'new or significantly improved' technology could be clarified to continue prioritizing innovation while better accounting for projects where factors like regional variation or combinations of existing technologies may merit Title XVII support.

Another financing mechanism to bolster investment in emerging or expanding clean energy technologies is green banks or climate banks. While there is currently no national green bank, proposals to establish one have been introduced in Congress. In addition, starting with the Connecticut Green Bank in 2011,[1071] a handful of states and local governments are implementing climate or green banks as a method of using public funds to spur private investment in clean energy or climate-related projects.

One of the other main ways the federal government supports clean energy R&D and sector growth is through tax incentives. Tax incentives have played an instrumental role in driving down the cost of clean energy, and continue to expand the market for clean energy and act as a market signal for not just deployment, but also R&D. However, there are ways we can improve and modernize these incentives to better accelerate innovation.

The credit for increasing research activities is the primary federal R&D tax incentive. The incentive includes portions of expenses for: 1) in-house or contracted R&D; 2) basic research; and 3) energy research conducted by an energy research consortium. The first two parts are for all sectors, though a higher percentage of certain R&D contract payments are included in credit calculations when they are energy-related. The R&D part covers technological research used to develop a new or improved business component (such as a product or process), related to a new or improved function, performance, reliability, or quality. Eligible research by the non-profit energy research consortiums includes, but is not limited to, clean energy. While the credit helps incentivize clean energy R&D, it is not tailored to climate innovation, and eligibility of R&D is frequently disputed. It is worth examining potential reforms, or alternate approaches to spurring increased private sector and NGO investments in climate innovation.

Deployment and commercialization can be viewed as a final step in the innovation pipeline, and a number of tax incentives play a critical role in helping spur sector growth. Some of these tax credits are temporary, termed 'extenders,' or phase down over time or after a cap is reached. A few of the main energy extenders are the renewable electricity production tax credit, business energy investment credit, credits for CCS or DAC, and advanced nuclear power production. Vehicle-related credits pertain to new qualified plug-in electric vehicles, alternative vehicles, and fuels and fueling equipment. There are also energy efficiency buildings credits for commercial buildings, home builders, and homeowners, and a renewables credit for homeowners.

The temporary nature of these incentives creates uncertainty, whereas longer-term incentives are more effective at spurring consistent private sector investment. In addition, technology-specific incentives often leave out new and promising technologies, like energy storage, and exclude any technologies that haven't been invented yet. There are two main potential approaches to addressing these limitations: improving and adding to current credits, or restructuring incentives.

Within our current tax structure, extenders are critical for producers, builders, consumers, and the market, and must be renewed. These credits can also be adjusted or supplemented to address additional important technologies and needs. Select examples of energy proposals include storage eligibility for energy investment credits and the residential energy efficient property credit; waste heat-to-power eligibility for the energy investment tax credits; removing the phasedown and extending the wind production and investment tax credits, including for offshore wind; increasing the credit for CCUS, and especially DAC; and creating a new investment tax credit for regionally significant transmission projects. A few other proposals include expanding electric vehicle credits, increasing renewable energy installation and renewable and energy efficient buildings credits for Tribes, creating a new credit for construction of all-electric homes, and renewing the expired advanced energy manufacturing investment credit.

Alternatively, the energy tax incentive structure itself could be adjusted. Under this approach, tax incentives could shift from being very temporary, often year-to-year, to being longer term, which could increase certainty and encourage more consistent investment. In addition, incentives could be formulated to be more flexible for new technologies, such as by making incentives emissions based and technology neutral. Effective new technologies could then benefit from credits more readily, without a patchwork of new credits. These types of changes could spur increased investment and better target incentives for new technologies, helping encourage innovation.

Calibrated and substantially increased federal funding and robust and well-targeted federal financing and tax incentives for RD&D and deployment are essential to achieving economy-wide decarbonization. Congress is currently the driving force behind such policies, and must prioritize modernizing, expanding, and strengthening them to better combat the existential threat of climate change. White House and federal agency support for robust funding, as well as forward-looking regulatory policies to accelerate clean energy and infrastructure innovation, is an essential complement to congressional action. The establishment of a national climate and clean energy innovation platform and new climate innovation council can aid these efforts. Such a council could provide a holistic assessment of where additional funding is most needed. It could also identify key drivers of climate-related innovation to enhance or replicate, ways to better bridge the valleys of death, and recommendations for adjustments to other policies (such as workforce development, intellectual property, or trade) that could advance U.S. climate innovation. American policymakers have come together before to support major clean energy and efficiency innovation, and such leadership is again required to reduce emissions, create new employment opportunities, and build a strong and clean economy.

DARK MONEY

> Giant fossil fuel corporations have spent billions—much of it anonymized through scores of front groups—during a decades-long campaign to attack climate science and obstruct climate action. Exposing the sources of this dark money and reforming our campaign finance and lobbying laws to require greater transparency will help create the conditions to pass bold, transformative climate legislation.

The United States is almost alone among industrialized nations in having failed to implement comprehensive policies to reduce greenhouse gas emissions. It is, of course, worth asking: why?

The short answer is undue influence from the leaders of giant fossil fuel corporations. These executives used weak American laws and regulations governing election spending, lobbying, and giving to advocacy groups to mount a massive covert operation.[1074] Their goal was to spread disinformation about climate change and obstruct climate action.[1075] The covert campaign spanned at least three decades, but its power decade followed the *Citizens United* decision in January 2010,[1076] a decision the industry asked for (masked by opaque intermediaries) and immediately put to use. Five Supreme Court justices appointed by Republican presidents gave fossil fuel executives a new and powerful political weapon: the ability to spend unlimited sums on elections. It did not take long for the operatives of this campaign to figure out how to use that weapon anonymously.

This single court decision cost us a lost decade on our journey to responsible climate legislation.[1077] It was already an uphill climb in the face of fossil fuel front groups' disinformation and lobbying pressure. *Citizens United* allowed fossil fuel political power to effectively capture Republican elected officials nationwide.

Prior to *Citizens United*, there had been a long history of bipartisanship on climate. In the 2000s, several bipartisan climate bills were circulating in the Senate, and one Republican senator even ran for president with a climate action pledge as part of his platform.[1078] But after that decision, bipartisan activity on comprehensive climate legislation collapsed as Republicans legislators fled from engagement.

Republican members who dared break with fossil fuel interests on climate found themselves facing primary challengers fueled by millions in industry dollars. Former South Carolina Republican Representative Bob Inglis was a prominent early casualty. His career in the House ended in 2010 by a primary challenger funded by fossil fuel interests angered by Inglis' support for putting a price on carbon pollution.[1079]

Fossil fuel executives realized that they only needed to keep one party in line, especially given Senate procedural rules that make it difficult to pass legislation without at least some bipartisan support. They made the strategic decision to target Republican officials. As the party traditionally more aligned with business interests—and more dependent on business interests for political funding—they were also an easier target.

Citizens United allowed brute political pressure to be deployed via unlimited spending in elections. Fossil fuel billionaires like the Koch brothers and executives from major fossil fuel corporations quickly figured out how to mask themselves and spend the money anonymously.[1080] Perhaps most troublesome, with the ability to spend unlimited sums came the power to threaten to spend unlimited sums. Along with their massive spending, fossil fuel interests could credibly and covertly wield the threat or promise of massive spending to keep Republican officials in line and acquire the loyalty of party leaders.

An added benefit of controlling one political party was the illusion it created of a partisan divide: Democrats were for climate action; Republicans were against. This partisan schema let the conservative media ecosystem—from talk radio, to influential blogs and websites, to Fox News—portray the climate change debate in partisan terms, rather than as simple, old-fashioned political corruption by a powerful special interest. The industry could spur a partisan response among rank and file conservatives, many of whom were likely already conditioned to be skeptical of climate change by the fossil fuel industry's decades-long disinformation campaign.

The *Citizens United* decision was premised on election spending being transparent, but special interests quickly hid their spending behind non-transparent front groups. Were an oil company to spend tens of millions of dollars on attack ads in its own name, the public would know to dismiss the ads as self-interested propaganda. But when oil companies run tens of millions of dollars through a trade association or a "social welfare" organization (behind a benign-sounding name like the "Heartland Institute" or "Americans for Prosperity" or the "Heritage Foundation"), the public is denied the true *dramatis personae* of the political performance acted out before them, and is left fooled. In effect, fossil fuel executives ran a political covert operation against their own country.

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Though the last decade was lost politically to these political machinations, the science and the facts—and the human experience of a changing climate—all continued. Under the pressure of reality, the climate denial and obstruction strategy is finally crumbling. But it is not yet dead.

In order to advance bold climate legislation, we must expose the covert influence of wealthy fossil fuel executives, trade associations, and front groups that have done everything possible to obstruct climate action. To counteract these forces, three key strategies are needed:

- ✔ Expose the role of the fossil fuel billionaires, executives, and corporations in funding and organizing the groups trafficking in climate denial and obstruction.
- ✔ Reform federal laws and regulations to require greater transparency and reduce the influence of money, particularly dark money, in politics.
- ✔ Alert industries that support climate action to the depth, nature, and success of the covert fossil fuel political influence scheme.

These actions can provide a path forward to durably changing the trajectory of climate action—and protect the American people from the dangers of climate change.

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What did they know and when did they know it?

The atmospheric warming properties of carbon dioxide have been understood for well over a century. In the 1850s, American amateur scientist Eunice Foote[1081] and Irish physicist John Tyndall[1082] showed that carbon dioxide and other gases have heat-trapping qualities in the atmosphere. In 1896, Swedish chemist Svante Arrhenius (who later won the Nobel Prize in chemistry) calculated that burning fossil fuels would add large amounts of carbon dioxide to the atmosphere, ultimately leading to warmer temperatures.[1083] In 1938, English engineer Guy Callendar compared historical concentrations of carbon dioxide in the atmosphere against the observed temperature record and concluded that higher carbon dioxide levels were likely responsible for higher observed temperatures.[1084]

These scientific advances were no secret to the fossil fuel industry. In 1959, at an event organized by the American Petroleum Institute (API) to celebrate the centennial of the American oil industry, the noted physicist Edward Teller explicitly warned the industry of the dangers that continued combustion of fossil fuels posed to the planet.[1085] Teller's address to oil industry luminaries included the following passage:

> Whenever you burn conventional fuel, you create carbon dioxide. [...] The carbon dioxide is invisible, it is transparent, you can't smell it, it is not dangerous to health, so why should one worry about it? Carbon dioxide has a strange property. It transmits visible light but it absorbs the infrared radiation, which is emitted from the earth. Its presence in the atmosphere causes a greenhouse effect [...] It has been calculated that a temperature rise corresponding to a 10 percent increase in carbon dioxide will be sufficient to melt the icecap and submerge New York. All the coastal cities would be covered, and since a considerable percentage of the human race lives in coastal regions, I think that this chemical contamination is more serious than most people tend to believe.[1086]

Teller's warning did not fall on deaf ears; the oil industry began to study climate change. In 1968, API received a report it had commissioned from the Stanford Research Institute. The report warned, "[s]ignificant temperature changes are almost certain to occur by the year 2000, and these could bring about climatic changes. [...] [T]here seems to be no doubt that the potential damage to our environment could be severe."[1087]

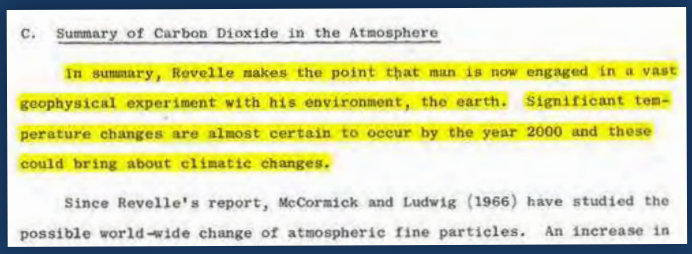
Individual oil companies also began having their own scientists study the problem. In 1977, one of Exxon's senior scientists told the company's management committee that "there is general scientific agreement that the most likely manner in which mankind is influencing the global climate is through carbon dioxide release from the burning of fossil fuels."[1088] The following year, he warned the company that doubling carbon dioxide in the atmosphere would result in a two to three degrees Celsius (3.6 to 5.4 degrees Fahrenheit) increase in average global temperatures.[1089] He added that "present thinking holds that man has a time window of five to 10 years before the need for hard decisions regarding changes in energy strategies might become critical."[1090]

Royal Dutch Shell's scientists came to similar conclusions. In 1988, Shell scientists wrote in an internal company report that atmospheric carbon dioxide concentrations could double by 2030, resulting in more than two degrees Celsius of warming.[1091] Shell's scientists predicted that sea levels would rise by at least one meter (3.3 feet) and by as much as five to six meters (16 to 20 feet) if warming led to the disintegration of the West Antarctic ice sheet.[1092] They also warned of the potential "disappearance of specific ecosystems or habitat destruction" due to climate change, anticipated an increase in "runoff, destructive floods, and inundation of low-lying farmland," and cautioned that "new sources of freshwater would be required" in certain newly arid areas.[1093] In sum, Shell's scientists warned that "the changes [caused by climate change] may be the greatest in recorded history."[1094]

Soon these scientific warnings would encounter the commanding economic imperatives of the oil industry; the outcome of that conflict would be perhaps predictable.

Figure 1: Select industry documents from the 1960s and 1970s discussing the likely impacts of burning fossil fuels

Report to API on The Sources, Abundance, and Fate of Gaseous Atmospheric Pollutants, 1968

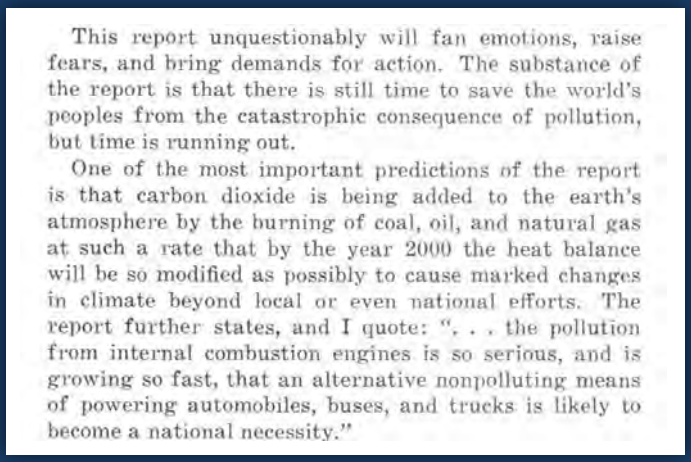


C. Summary of Carbon Dioxide in the Atmosphere

In summary, Revelle makes the point that man is now engaged in a vast geophysical experiment with his environment, the earth. Significant temperature changes are almost certain to occur by the year 2000 and these could bring about climatic changes.

Since Revelle's report, McCormick and Ludwig (1966) have studied the possible world-wide change of atmospheric fine particles. An increase in

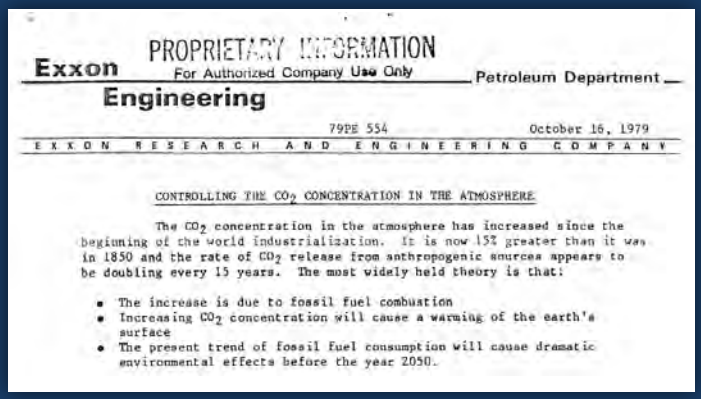
API President Frank Ikard's 1965 speech on climate change and fossil fuels



This report unquestionably will fan emotions, raise fears, and bring demands for action. The substance of the report is that there is still time to save the world's peoples from the catastrophic consequence of pollution, but time is running out.

One of the most important predictions of the report is that carbon dioxide is being added to the earth's atmosphere by the burning of coal, oil, and natural gas at such a rate that by the year 2000 the heat balance will be so modified as possibly to cause marked changes in climate beyond local or even national efforts. The report further states, and I quote: ". . . the pollution from internal combustion engines is so serious, and is growing so fast, that an alternative nonpolluting means of powering automobiles, buses, and trucks is likely to become a national necessity."

Internal Exxon memo, 1979



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Exxon Engineering — Petroleum Department

79PE 554 — October 16, 1979

EXXON RESEARCH AND ENGINEERING COMPANY

CONTROLLING THE CO_2 CONCENTRATION IN THE ATMOSPHERE

The CO_2 concentration in the atmosphere has increased since the beginning of the world industrialization. It is now 15% greater than it was in 1850 and the rate of CO_2 release from anthropogenic sources appears to be doubling every 15 years. The most widely held theory is that:

- The increase is due to fossil fuel combustion
- Increasing CO_2 concentration will cause a warming of the earth's surface
- The present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050.

Enter Congress

The oil and gas industry was not the only entity to take note of emerging scientific concerns about what continued fossil fuel combustion would do to the climate, the planet, and civilization.

In 1986, the Subcommittee on Environmental Pollution of the Senate Environment and Public Works Committee (EPW), chaired by Senator John Chafee (R-RI), held two days of hearings on climate change.[1095] Over those two days, the Subcommittee heard from scientists and government experts that combustion of fossil fuels was driving an increase in atmospheric carbon dioxide which would likely have dramatic and severe consequences for the climate.[1096] Following these hearings, Chafee, together with two Republican colleagues and three Democratic colleagues on EPW, wrote to the congressional Office of Technology Assessment to request that it analyze policy options to stabilize or reduce the concentration of greenhouse gases in the atmosphere. Their letter concluded, "[d]ue to the likelihood that legislation will be seriously considered by the Committee early in the next Congress, it would be most helpful if this analysis could be undertaken without delay."[1097]

In 1988, National Aeronautics and Space Administration (NASA) scientist James Hansen, one of the witnesses at the 1986 EPW hearings, testified before the Senate Energy and Natural Resources Committee about the dangers of climate change.[1098] This time, perhaps in part because the summer of 1988 was unprecedentedly hot in the United States and Yellowstone National Park burned, the scientific warnings about climate change seemed to break through with the general public and policymakers.

Thirty-two separate climate-related bills were introduced in Congress that year, including many by Republicans.[1099] Perhaps the most prominent was the National Energy Policy Act, introduced in the Senate by Senator Tim Wirth (D-CO) and cosponsored by 18 senators, including five Republicans.[1100] The National Energy Policy Act targeted reducing atmospheric carbon dioxide concentrations by 20 percent by 2000 compared to 1988.[1101] Rhode Island Republicans, Senator Chafee and Representative Claudine Schneider, introduced the Global Warming Prevention Act; the House version of the bill was

cosponsored by 39 members, including 14 Republicans.[1102] Similar to the National Energy Policy Act, the Global Warming Prevention Act established a target to reduce atmospheric carbon dioxide concentrations, and incentivized energy efficiency and the development of renewable energy.[1103]

Congress was not alone in responding to the scientific warnings about climate change. During the 1988 presidential race, both candidates were committed to climate action, with Republican George H. W. Bush famously declaring "[t]hose who think we are powerless to do anything about the greenhouse effect forget about the 'White House effect.' [...] As president, I intend to do something about it."[1104]

These political stirrings would soon also encounter the commanding economic imperatives of the oil industry; the outcome of that conflict was perhaps also predictable.

Fossil fuel executives strike back

Fossil fuel industry leaders had heard about climate change risks from their own scientists. They had watched the public become increasingly concerned about climate change, they saw momentum gather in Congress and the White House for action to reduce the demand for its products—and they sprang into action. As Harvard professor Naomi Oreskes testified before the Special Committee, "If you look at the timing of when [fossil fuel industry-funded groups] really started getting going in a big way, it's during [the George H.W. Bush administration]. So as long as scientists were just doing science and publishing in peer-reviewed journals, the fossil fuel industry wasn't really too worried, but when political action began to be taken, that's when we begin to see the [climate] denial campaign kick in."[1105]

Luckily for the fossil fuel executives (if unluckily for the planet), another industry's leaders had spent decades lying about the dangers associated with its product, and had a playbook for how to sow doubt about science and block action in Congress: the tobacco industry. Dr. Oreskes testified that "the strategies and tactics used by the fossil fuel industry to deny the harms of fossil fuel use were in many cases the same as those used by the tobacco industry to deny the harms of tobacco use. [...T]his was no coincidence, because many of the same individuals, PR firms, advertising agencies, and institutions were involved in both."[1106] As tobacco's denial scheme collapsed, its machinery moved readily into climate denial.

Critical to this scheme were front groups to obscure the role of the fossil fuel billionaires and corporations. Front groups took many forms: "think tanks," non-governmental organizations (NGOs), and non-profit associations. Many were incorporated as organizations under sections 501(c)(3) and 501(c)(4) of the tax code, to help keep the identity of donors secret.

> "[T]he strategies and tactics used by the fossil fuel industry to deny the harms of fossil fuel use were in many cases the same as those used by the tobacco industry to deny the harms of tobacco use. [...T]his was no coincidence, because many of the same individuals, PR firms, advertising agencies, and institutions were involved in both."[1159]
>
> **— Dr. Naomi Oreskes**
> *Professor, Harvard University*

Fossil fuel executives also coopted existing groups to block climate action in Congress. They focused particularly on capturing big business trade associations. This tactic augmented the industry's web of manufactured denial groups with an array of existing industry associations whose broad membership suggested that they were speaking for the business community rather than just the fossil fuel industry. Trade associations are incorporated under section 501(c)(6) of the tax code, which also helps obscure donor identities.

The dogged work of investigative reporters and researchers has revealed details about this hidden funding, and allows us to draw these conclusions. However, most information about these front groups remains cloaked in secrecy. The full story is probably worse than we know; otherwise, why the persistent effort to hide it?

FRONT GROUPS. The Global Climate Coalition (GCC) was one of the first front groups created by fossil fuel executives. Founded in 1989 in the midst of the public's climate awakening, its members included oil companies—Chevron, Exxon, Mobil, Shell, and Amoco (now part of BP) —and trade associations like API, the National Association of Manufacturers, and the U.S. Chamber of Commerce.[1107] The GCC's public position on climate change, belied by oil companies' own internal research, was that "there is no convincing evidence that future increases in greenhouse gas concentrations will produce significant climatic effects."[1108]

The GCC worked to shape public opinion and to influence policymakers. As U.N. negotiations aimed at limiting carbon emissions gathered steam in Kyoto, Japan in 1997, the GCC spent $13 million on a U.S. ad campaign against climate action.[1109] State Department documents reveal that President George W. Bush eventually rejected the Kyoto Protocol "in part based on input from [the GCC]."[1110] As more details filtered out about the GCC and its role as a fossil fuel front group, it lost its usefulness and was disbanded in 2002.[1111]

The Heartland Institute is another prominent front group funded by the fossil fuel industry to sow doubt about climate science. Founded in 1984, Heartland promotes itself as a think tank. It originally advocated for policy positions at the behest of several industries, including the tobacco industry.[1112] In the 1990s Heartland began to engage primarily in anti-climate work as donations from the fossil fuel industry ramped up.

In 2012, a Heartland campaign to attack climate scientists claimed that "the most prominent advocates of global warming aren't scientists. They are murderers, tyrants, and madmen."[1113] The campaign featured billboards of Unabomber Ted Kaczynski, mass murderer Charles Manson, and dictator Fidel Castro.[1114]

In 2017, Heartland sent more than 200,000 "textbooks" to schoolteachers across the country.[1115] These books purported to show that the science around climate change was uncertain and that even if climate change was occurring, it was not harmful.[1116] Who exactly paid to print and mail these 200,000 books is a Heartland secret.

Heartland's funding has become steadily more opaque. While it is known that Heartland has received funding from ExxonMobil, API, and groups associated with the fossil fuel billionaire Koch brothers,[1117] Heartland increasingly relies on middlemen acting as donor-advised charities for its funding. Donor-advised charities permit wealthy individuals and corporations to separate their identities from their donations, which are reported in the name of the supposed charity.[1118]

A recent undercover investigation revealed the extent of donor-advised charity funding for Heartland. A senior official at Heartland told undercover reporters posing as auto industry lobbyists that the donor-advised charity Donors Trust provides between two thirds and three quarters of Heartland's budget for attacking climate science and obstructing climate action.[1119] The Heartland official told the "lobbyists" that if their client car company would fund Heartland, he would provide scientists to claim that auto emissions from fossil fuel combustion did not have negative health effects.[1120] One of the scientists Heartland offered up to spread disinformation was Steve Milloy, who has a long history working for the tobacco and fossil fuel industries.[1121]

These three front groups are a few among many. A scientific subspecialty has emerged studying the social, economic, political, and rhetorical aspects of the climate denial apparatus. Peer-reviewed reports in this field count fossil fuel front groups at well over 100, with different front groups activated and deactivated at different times.[1122]

FRONT GROUPS: HOW MAJOR BRANDS FUND CLIMATE DENIAL

The Competitive Enterprise Institute (CEI) is one of the most influential anti-climate front groups, with a long history of opposing efforts to safeguard the environment. CEI even opposed international action to phase out the chlorofluorocarbons (CFCs) responsible for the "ozone hole" in the atmosphere.[1160] CEI claimed that phasing out CFCs would lead to huge cost increases for consumers and major reliability problems with cooling equipment.[1161] None of CEI's predictions came true when CFCs were phased out.[1162]

CEI's failed CFCs campaign provides a template for its current campaign against climate action. The CEI playbook is simple: muddy the waters, dispute the science, make wild claims about the costs of action, and ignore the costs of inaction. America Misled, a report on the disinformation campaign funded by fossil fuel interests, provides ample additional information on this climate denial playbook.[1163]

CEI's anti-climate campaign is run by Myron Ebell. Ebell has a long history of disputing well-settled climate science, including saying in 2005 that "we've always wanted to get the science on trial."[1164] In 2006, CEI funded a TV ad campaign defending carbon pollution, by extolling carbon dioxide itself. The ads' tag line? "Carbon dioxide? They call it pollution. We call it life."[1165] During the Obama presidency, CEI consistently opposed all of the administration's efforts to reduce carbon pollution.[1166]

When Donald Trump was elected, CEI went on offense. Ebell was chosen to lead Trump's transition team at EPA,[1167] and he later proposed that a panel of "experts" under the National Security Council should promote alternative, non-scientific explanations of climate change.[1168]

CEI's anti-climate crusade costs money. In 2016, CEI reported having received over $7 million in donations.[1169] Because groups like CEI hide their donors, it is impossible to know precisely who funds it, but reporters have learned that CEI has received generous funding from fossil fuel companies like ExxonMobil, from the fossil fuel billionaire Koch brothers, and from the Koch-affiliated donor-advised charity, Donors Trust.[1170] Fossil fuel interests are not the only ones funding CEI. The New York Times has publicly reported that corporations like Amazon, AT&T, Google, T-Mobile, and Verizon all fund CEI.[1171]

Consumers have a powerful tool to effect change: image-conscious companies do not want to risk hurting their brands by association with climate denial and obstruction. Consumers are making clear to major brands that they will not tolerate companies supporting climate denial and obstruction, but this consumer power is thwarted by the covert nature of the climate denial and obstruction campaign.

TRADE ASSOCIATIONS. Over the last two decades, the top five spenders on lobbying have all been big corporate trade associations.[1123] Trade associations do not just lobby. Some spend big money in political elections, some send lawyers to challenge agency rulemakings in agencies and courts, and some sponsor public relations campaigns to improve the public image of an industry. Some do all of the above.

Most trade associations are industry-specific. Coal mining companies and other mining interests are represented by the National Mining Association. Oil and gas companies have multiple trade associations representing their interests. The largest is API, which has spent more than $120 million lobbying the federal government over the last two decades.[1124] Other influential oil and gas trade associations include the American Fuel and Petrochemical Manufacturers, the American Gas Association, and the Independent Petroleum Association of America.

Some associations represent a broader coalition of business interests. The U.S. Chamber of Commerce and the National Association of Manufacturers (NAM) are two powerful trade associations with broad-based memberships made up of companies from diverse industrial sectors. With a large majority of their members from outside the fossil fuel industry, and with many members touting their own sustainability programs, one might expect these associations would not be hostile to climate action. Unfortunately, that is not the case. Dylan Tanner of the watchdog group InfluenceMap testified before the Special Committee that these groups "tend to adopt the lowest common denominator positions on climate of their most oppositional members."[1125] InfluenceMap found that the Chamber and NAM were the two most influential opponents of climate action, even more than fossil fuel industry trade associations such as API.[1126]

> "[Trade associations] tend to adopt the lowest common denominator positions on climate of their most oppositional members."[1172]
>
> **— Dylan Tanner**
> *Executive director and co-founder, InfluenceMap*

Figure 2: 10 Most Obstructive Trade Associations on Climate Policy

CLIMATE POLICY IMPACT SCORE	TRADE ASSOCIATION
-86.4	National Association of Manufacturers
-86.2	U.S. Chamber of Commerce
-81.5	American Legislative Exchange Council
-66.5	National Mining Association
-64.5	American Petroleum Institute
-60.9	International Air Transport Association
-41.2	European Chemical Industry Council
-38.1	American Coalition for Clean Coal Energy
-37.8	BusinessEurope
-33.6	Japanese Business Federation (Keidanren)

Adapted from InfluenceMap, December 2017

How did this happen? In our experience, industries use the Chamber to do their political work; so members do not look too hard at the Chamber doing other industries' political work. Fossil fuel funding may explain the Chamber's behavior, but it is hard to follow the money because of Chamber secrecy. The Chamber does not disclose its fossil fuel funding. Thus, the Chamber's role as one of America's worst climate obstructers came as an unpleasant surprise to many members.

It is important to distinguish the U.S. Chamber from local chambers of commerce operating in communities across the country. Many local chambers have been promoters of clean energy development as an opportunity to bolster local economies and boost climate resilience.[1127] The U.S. Chamber has taken a different tack and is focused almost exclusively on promoting fossil fuels.[1128]

As mentioned above, trade associations do far more than lobby. The Chamber, for example, is one of the largest spenders of undisclosed donations, or "dark money," on elections ads. Its ads almost always support the candidate most opposed to climate action.[1129] The Chamber is also a prolific litigator, having been a party or *amicus curiae* in hundreds of cases.[1130] It frequently defends energy interests in court, and has sued the EPA more than any other agency, often to challenge agency actions limiting greenhouse gas (GHG) emissions.[1131]

API, beyond its lobbying, spends large amounts of money on public relations advertising to burnish the image of the oil and gas industry. This year, it launched a seven-figure nationwide advertising campaign featuring the tagline "We're on it."[1132] These ads painted the oil and gas industry as taking responsible steps to limit GHG emissions, while API was busy lobbying to gut regulations that limit GHG emissions.[1133]

Trade associations, like the industry's own front groups, provide the fossil fuel industry cover to distance itself from anti-climate lobbying and political influencing activities. The Honest Leadership and Open Government Act requires trade associations to either list their membership on their website or disclose the members that provide more than $5,000 a quarter for lobbying activities and "actively participate in the planning, supervision, or control of such lobbying activities."[1134] Not all trade association comply with this requirement[1135] and there has been little enforcement. Since trade associations typically do not disclose the identity of members funding their electioneering, litigation, or public relations efforts, it is usually impossible to determine which members are actually calling the shots behind trade association activities.

A flagrant example is the oil industry's response to EPA's proposal to roll back methane regulations. ExxonMobil, Shell, and BP, three of API's largest members, all claimed they opposed EPA's proposal; API supported it.[1136] It is impossible for the public to tell if the oil majors' opposition was genuine or if it was public relations, with their real message conveyed to the EPA by their trade association. Tom Donohue, CEO of the Chamber, once admitted: "I want to give [my members] all the deniability they need."[1137]

TRADE ASSOCIATIONS: HOW MAJOR BRANDS FUND CLIMATE DENIAL

Many major companies talk a good game on climate. Many are also taking serious steps to reduce their own corporate carbon emissions. But emissions reduction efforts by corporations, universities, and other private actors can't produce the reductions needed to avoid the worst effects of climate change.[1173] To reach our emissions reduction goals, federal action is necessary. For corporations, the most powerful tool in the fight against climate change is political effort.[1174] Few make any. And many ostensibly pro-climate American companies fund trade associations like the U.S. Chamber of Commerce, giving their support to one of the most influential groups opposed to climate action.

The Chamber is by far the largest lobbyist in Washington, having spent more than $1.6 billion lobbying the federal government over the last two decades. That is almost three times more than the next largest spender.[1175] The Chamber has also been one of the largest dark money spenders on congressional races,[1176] having spent almost $150 million since *Citizens United*. Almost all was spent on candidates opposed to climate action.[1177] Many of its ads attacked candidates for supporting good climate policies.[1178]

Look at the Chamber's record of opposing measures to reduce carbon pollution:

- In 2009, it was one of the lead opponents of the Waxman-Markey cap-and-trade legislation to reduce carbon pollution, which had bipartisan support.[1179]

- Having successfully killed the 2009 federal climate legislation, the Chamber next sued EPA in 2010 to overturn its finding that GHG emissions endanger public health and welfare.[1180]

- Beginning in 2014, the Chamber convened fossil fuel industry lobbyists, lawyers, and political strategists to plot legal strategies to oppose regulatory actions limiting carbon pollution.[1181]

- In 2015, the Chamber led a coalition of trade associations suing to block EPA's proposed Clean Power Plan (CPP) to reduce carbon emissions in the electric power sector.[1182]

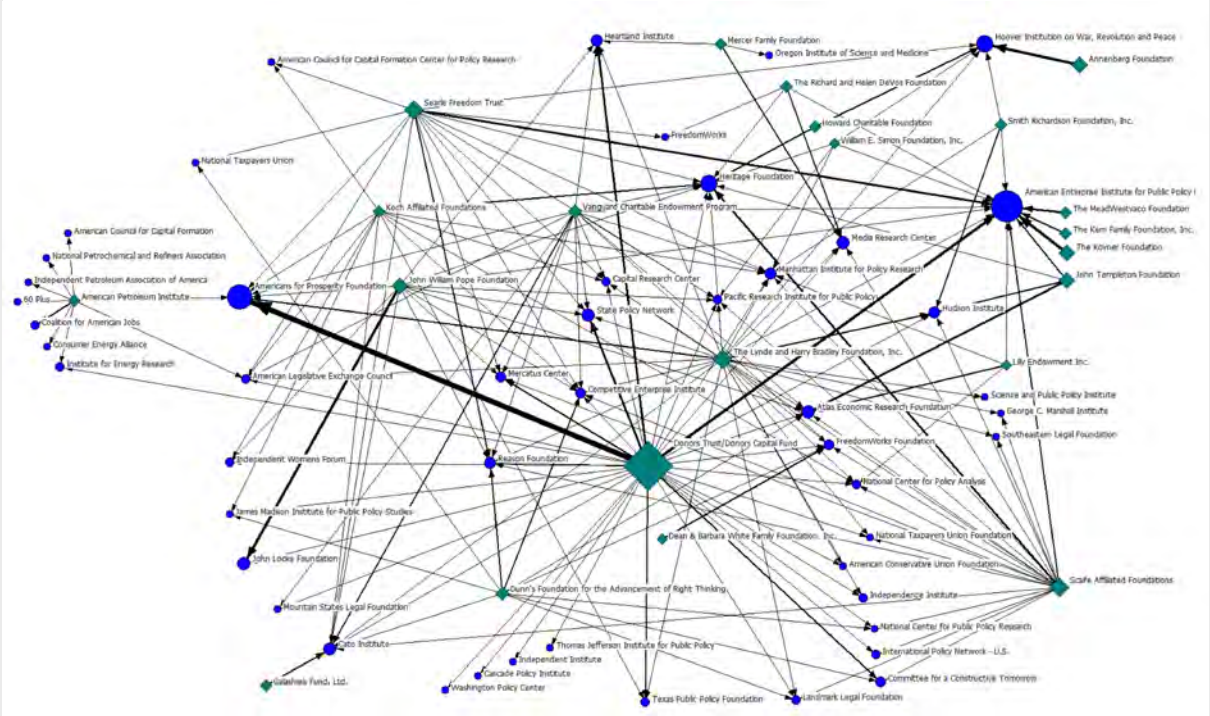
- In 2017, the Chamber funded a widely-debunked study critical of the Paris Agreement;[1183] President Trump later cited this study in his justification for withdrawing from the agreement.[1184]

- In 2019, the Chamber intervened in the litigation challenging the Trump administration's plans to rescind the CPP and replace it with the so-called Affordable Clean Energy Rule, which would do nothing to reduce carbon pollution; the Chamber is supporting the administration's do-nothing rule.[1185]

This is what corporate America pays for through Chamber membership. A few companies have quit the Chamber over its anti-climate activities;[1186] many more continue to fund the Chamber despite its role in climate obstruction.

Perhaps the most important unknown in this scheme is how much money fossil fuel executives directed to the Chamber in the last decade. The leading trade associations with records of climate obstruction appear not to have been asked by their member corporations for a full or public accounting of the associations' fossil fuel funding, nor for any review of the linkage between such funding and their organizations' records of climate obstruction.

Figure 3: The connections and flow of funding between climate denial groups in 2010. The size of the symbol and lines indicate the relative amount of funding.[1187]



The web of denial and obstruction

By the time *Citizens United* was decided in January 2010, fossil fuel executives had created and organized an astonishingly large array of front groups and trade associations to sow doubt about climate science and to obstruct climate action by policymakers. Yale professor Dr. Justin Farrell testified before the Special Committee that this network of anti-climate groups is made up of between 160 and 200 individual organizations.[1138] This number fluctuates with time, as groups are created, dissolved, and then restarted under new names in a rolling shell game that makes it hard to identify who is actually behind the scheme.[1139] ExxonMobil, for instance, funded 39 different anti-climate groups in a single year.[1140]

There is big money behind this operation. An analysis of 91 anti-climate groups revealed that they collectively reported more than $7 billion in funding over an eight-year period, or more than $900 million per year on average.[1141] The largest source of money from foundations for these groups was the Koch-affiliated identity remover, Donors Trust;[1142] and funding from donor-advised charities such as Donors Trust was increasing, perhaps as donors became more and more concerned about covering their tracks.[1143] Research also shows that funding often flows through multiple organizations, creating a Russian nesting doll of anonymizing shells protecting the donors' identity.[1144]

This web of groups is a true network, with numerous connections among the groups and their funders.[1145] The overlapping connections include donors, board members, staff, money flow, and mail drop addresses. It is not happenstance that scores of anti-climate groups all exist; it is by design. This network was created by fossil fuel industry leaders to create the illusion of an organic grassroots movement; and to have more shells to hide behind, creating a "front group whack-a-mole" apparatus; all to better mislead the public, the press, and policymakers.

A path to victory

If the United States Congress is to pass comprehensive climate legislation—legislation that will reduce carbon emissions to truly safe levels—stakeholders will need to address this fossil fuel-funded web of denial and obstruction. Members of Congress, outside stakeholders, and concerned citizens all have a role to play. There are three key tasks:

1. Expose the role of the fossil fuel billionaires, executives, and corporations in funding and organizing the groups trafficking in climate denial and obstruction, so the public is not fooled.

2. Reform federal laws and regulations to require greater transparency and reduce the influence of money, particularly dark money, to limit corruption in politics.

3. Alert industries supporting climate action to the danger presented by the fossil fuel covert political influence operation.

EXPOSE. There are several things Congress can do to expose fossil fuel industry funding. First, Congress should investigate which entities fund which groups. It is not in the public interest for powerful political forces to mount covert operations in America to subvert the operation of our own government. As congressional scholar Morton Rosenberg testified before the Special Committee, Congress has broad powers to conduct investigations and compel the production of evidence related to matters of legitimate legislative interest.[1146]

The legislative interests in such an investigation are legion. Understanding the extent to which fossil fuel executives and corporations fund tax exempt groups incorporated under sections 501(c)(3), 501(c)(4), and 501(c)(6) of the tax code would help Congress determine whether current laws governing campaign finance and lobbying adequately protect the public interest. Answering the question of who knowingly caused harm by delaying climate action will inform legislative efforts to assign the massive current and future costs of the climate crisis. Another legitimate inquiry is whether charitable 501(c)(3) organizations and 501(c)(4) social welfare groups are being inappropriately used not for public benefit but to further pecuniary interests of their funders.

Congressional committees could as a rule start requiring that witnesses from non-profit organizations disclose the funding their organizations have received from interests with a financial stake in the subject matter upon which they have been called to testify. Witnesses from trade associations and fossil fuel-funded front groups frequently testify before Congress on matters related to environmental and energy policy without such disclosure. Members and the general public cannot properly assess the motives and credibility of such witnesses, a point underscored by Dr. Oreskes' testimony to the Special Committee describing her experience testifying before a congressional committee with another witness from a fossil fuel front group.[1147]

REFORM. New regulations or laws requiring greater transparency would be helpful.

The Securities and Exchange Commission (SEC) should initiate a rulemaking to require registered companies to disclose all of their spending on political influence activities, including money funneled to trade associations and other politically active non-profits. In 2011, a bipartisan group of experts submitted a petition for such a rulemaking to the SEC.[1148] Naturally, fossil fuel-funded front groups and trade associations, including the U.S. Chamber of Commerce, vehemently opposed this rulemaking.[1149] Republicans in Congress swiftly inserted language into legislation funding the SEC to prohibit the agency from further work on this rulemaking.[1150]

Congress should pass legislation requiring transparency in political and election spending. It is wrong, and a recipe for corruption, when only the donor and the beneficiary and their agents know of massive, hidden political spending. Moreover, the problem of threats and promises is an incurable flaw in any regime allowing massive political donations and spending. In 2012, the Senate twice voted on cloture to advance transparency legislation; both times Republicans blocked it on a party-line vote.[1151] In the current Congress, political spending transparency provisions are included in H.R. 1, the For the People Act of 2019,[1152] which the House of Representatives passed in March 2019 on a party-line vote.[1153] As of July 2020, Republican leadership in the Senate have refused to allow a vote on the bill.

Congress should update and enforce the Honest Leadership and Open Government Act of 2007 (HLOGA).[1154] The law brought some needed transparency to lobbying, but much remains hidden behind legal loopholes and lax enforcement. Companies still use trade associations to dodge public accountability for their political efforts. And the U.S. Chamber refuses to comply with HLOGA's requirement that it disclose its members that pay for and direct its lobbying activities.[1155] Not-for-profit organizations organized under sections 501(c)(3) and (c)(4) of the Internal Revenue Code issue policy papers and analyses that are not considered direct lobbying, but are drafted and used for lobbying purposes in Congress, all without disclosing their donors. Congress needs to ensure that big-dollar lobbying and other influencing activities are transparent; anything less than full transparency demeans the American citizen.

Anti-climate political strategy is largely based on deception and bullying. Tactics such as those put a premium on anonymity and obfuscation. Disastrous decisions like *Citizens United* constrain Congress's ability to limit special interest spending on elections, but Congress and independent agencies can at least expose the hidden spending to the public. The sunshine of transparency will help create a more honest and honorable government, and that will enhance the conditions for victory on climate, as it will require fossil fuel corporations and their executives to take ownership of, or abandon, the reprehensible tactics they have used to block comprehensive climate legislation. It is wrong for powerful special interests to operate covertly through a manufactured web of denial and obstruction.

ALERT. The fossil fuel industry enjoys direct and indirect subsidies that the International Monetary Fund has estimated at over $600 billion per year in the United States alone.[1156] To defend a prize like that, fossil fuel executives and their allies will spend whatever they need to spend to protect their interests. That includes both blocking legislation that would reduce their GHG emissions and blocking reforms that would disclose their covert political operation. With a $600 billion annual

incentive behind their political influence activities, industry forces will never stop until good people and honorable corporate interests stand up to stop them. The incentives are just too strong for them ever to stop on their own.

This report documents the looming economic costs and risks associated with climate change. The prospect of "systemic" economic crashes gives some industries an incentive to mitigate climate change. Climate-exposed sectors such as insurance, banking, coastal real estate, and agriculture see their own danger becoming ever greater and ever clearer. Climate concern is therefore moving within many companies from the public relations and investor relations departments into the risk management and strategic planning departments. Corporate America increasingly realizes the massive costs it may bear associated with unmitigated climate change. As a result, tiny, tentative efforts have begun in pro-climate companies to exert political effort in Washington for climate action. To date, nothing serious has happened, but it seems that change is coming. Time is short, however.

The overall political stance of corporate America outside the fossil fuel sector has largely been hostile to climate action: there has been little positive interest or effort from companies; and the big trade associations, coopted by fossil fuel interests, have been powerful negative forces. The net political effect is overall corporate opposition to climate action. Corporations with good internal climate policies simply do not show up in Congress; fossil fuel forces do, remorselessly (and often anonymously). It's hard to win a game when you do not show up; it is worse when you appoint as your agent a trade association who is working for the other team.

The Environmental Defense Fund (EDF) has pointed out that corporate America's most powerful tool in the fight against climate change is its political clout.[1157] Internal corporate sustainability measures alone will never avert the crisis. Federal climate action is necessary so no corporation can credibly claim to be a leader on climate and sustainability if it is not making sincere political effort to support climate action in Washington.

Pressure is mounting. A few investors have begun telling companies to assure that trade associations and other groups the companies fund align their climate advocacy with the Paris Agreement.[1158] The Chamber, under pressure from members, has dialed back some of its more obvious anti-climate activities. Depending on how egregious the trade association misbehavior was, member companies may even face liability for due diligence failures at monitoring their trade association's misbehavior. But well short of legal liability, the disconnect when a company touts its green bona fides while supporting climate obstruction presents reputational risk.

Imagine if the political polarities on climate change suddenly reversed. Imagine if the big trade associations were led by the science and the economics of climate change, not by fossil fuel money. Imagine how quickly Congress could act if powerful trade associations like the U.S. Chamber of Commerce and National Association of Manufacturers became advocates for serious pro-climate policies. Imagine if the powerful banking, agricultural, financial services, technology, and consumer products lobbies came in and demanded real climate action.

Corporate America need not imagine this. Corporate America can make it happen. When it decides to show up.

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- Committee on Environment and Public Works
- Committee on Energy and Natural Resources
- Committee on Agriculture, Nutrition, and Forestry
- Committee on Homeland Security and Governmental Affairs
- Committee on Banking, Housing, and Urban Affairs
- Committee on Health, Education, Labor, and Pensions
- Committee on Finance
- Committee on Armed Services
- Committee on Foreign Relations
- Committee on Indian Affairs
- Committee on Commerce, Science, and Transportation

The Special Committee held 10 hearings, hosted 12 in-depth meetings with stakeholder groups, and solicited input from several at-risk communities and the general public. The Special Committee thanks the following individuals for testifying and participating in these hearings and meetings.

Hearings:

A Blueprint for Success: U.S. Climate Action at the Local Level (July 2019)

- Mayor Keisha Lance Bottoms, Atlanta, GA
- Mayor Kirk Caldwell, Honolulu, HI
- Mayor Melvin Carter, Saint Paul, MN
- Mayor William Peduto, Pittsburgh, PA
- Mayor Ted Wheeler, Portland, OR

The Right Thing to Do: Conservatives for Climate Action (July 2019)

- Dr. Frank Luntz, founder and CEO, FIL, Inc.
- Kiera O'Brien, vice president of Students for Carbon Dividends
- Nick Huey, founder of the Climate Campaign

The Fight to Save Winter: Pro Athletes for Climate Action (September 2019)

- Mike Richter, president of Brightcore Energy; Hall of Fame goaltender for the New York Rangers
- Jeremy Jones, founder of Protect Our Winters; professional snowboarder
- Caroline Gleich, professional ski mountaineer and adventurer
- Tommy Caldwell, professional climber

Dark Money and Barriers to Climate Action (October 2019)

- Dr. Justin Farrell, professor, Yale University School of Forestry and Environmental Studies
- Dr. Naomi Oreskes, professor, Harvard University
- Morton Rosenberg, congressional scholar, Project on Government Oversight
- Dylan Tanner, executive director & co-founder, InfluenceMap

Perspectives from the Front Lines: How Climate Change Uniquely Impacts Environmental Justice Communities (November 2019)

- Dr. Cecilia Martinez, co-founder and executive director, Center for Earth, Energy, and Democracy
- Michele Roberts, national co-coordinator, Environmental Justice Health Alliance for Chemical Policy Reform
- Celeste Flores, outreach director, Faith in Place

Better, Stronger, Smarter: Building Community Resilience in a Future of Extremes (December 2019)

- Alice Hill, senior fellow for climate change policy, Council on Foreign Relations
- Laura Lightbody, project director, Pew Charitable Trusts Flood-Prepared Communities
- Mayor Tim Kabat, La Crosse, WI

Understanding and Combating the Security Risks of Climate Change (February 2020)

- Rear Admiral Ann C. Phillips, United States Navy (retired)
- The Hon. John Conger, director, Center for Climate and Security
- Andrew Holland, chief operating officer, American Security Project

The Economic Risks of Climate Change (March 2020)

- The Hon. Sarah Bloom Raskin, former member of the Federal Reserve Board of Governors and Deputy Treasury Secretary
- Dr. Bob Litterman, founding partner and Risk Committee chairman, Kepos Capital; chair of the Climate-Related Market Risk Subcommittee, Commodity Futures Trading Commission
- Dave Burt, CEO and founder, DeltaTerra Capital
- Frédéric Samama, head of responsible investment, Amundi; co-author of "The green swan: Central banking and financial stability in the age of climate change"

Quality Jobs, Lower Emissions: Decarbonizing the Energy and Industrial Sectors while Expanding Opportunities for American Workers (July 2020)

- The Hon. Ernest Moniz, former U.S. Secretary of Energy; founder and CEO, Energy Futures Initiative
- Tom Conway, international president, United Steelworkers (USW)

Safely, Efficiently, and Equitably: Transportation Solutions to Move People and Goods in a Decarbonized Economy (July 2020)

- Vivian Satterfield, director of strategic partnerships, Verde
- Jeff Allen, executive director, Forth
- Brad Schallert, director of carbon market governance and aviation, World Wildlife Fund
- Rachel Muncrief, deputy director, International Council on Clean Transportation

Meetings:

Utility executives (June 2019)

- Alan Oshima, president and CEO, Hawaiian Electric
- Bill Johnson, president and CEO, PG&E
- Maria Pope, president and CEO, Portland General Electric
- Terry Sobolewski, president, National Grid Rhode Island
- Eric Olsen, vice president and general counsel, Great River Energy

Labor leaders (July 2019)

- Richard Trumka, president, AFL-CIO
- Liz Shuler, secretary-treasurer, AFL-CIO
- Sean McGarvey, president, North America's Building Trades Unions (NABTU)
- Cecil Roberts, president, United Mine Workers of America (UMWA)
- Terry O'Sullivan, general president, Laborers' International Union of North America (LIUNA)
- Paul Shearon, international president, International Federation of Professional and Technical Engineers (IFPTE)
- Warren Fairley, international vice president for Southeast, International Brotherhood of Boilermakers
- Austin Keyser, director of political and legislative affairs, International Brotherhood of Electrical Workers (IBEW)

New York Renews (September 2019)

- Eddie Bautista, executive director, New York City Environmental Justice Alliance
- Elizabeth Yeampierre, executive director, UPROSE
- Stephan Edel, director, New York Working Families
- Maritza Silva-Farrell, executive director, ALIGN
- Lisa Tyson, executive director, Long Island Progressive Coalition
- Marc Weiss, former board member, Sierra Club

United Nations (September 2019)

- Ambassador Luis Alfonso de Alba of Mexico, Special Envoy of the Secretary-General for the 2019 Climate Action Summit

Youth climate activists (September 2019)

- Alexandria Villaseñor, co-founder, U.S. Youth Climate Strike; founder, Earth Uprising
- Jonah Gottlieb, founding youth member, National Children's Campaign
- Levi Draheim, *Juliana v. United States* plaintiff
- Kevin Patel, co-deputy partnerships director, Zero Hour
- Lana Weidgenant, co-deputy partnerships director, Zero Hour
- Rachel Lee, head coordinator, Zero Hour NYC
- Daphne Frias, global outreach team, Zero Hour

Special thanks for hosting: United Nations Foundation

Financial industry executives (September 2019)

- Roger Ferguson, president and CEO, TIAA
- Douglas Peterson, president and CEO, S&P Global
- Raymond McDaniel, Jr., president and CEO, Moody's
- Edward Skyler, executive vice president for global public affairs, Citi

Special thanks for hosting: Bloomberg LP

Signatories to the Equitable and Just National Climate Platform (October 2019)

- Dr. Cecilia Martinez, co-founder and executive director, Center for Earth, Energy, and Democracy
- Michele Roberts, national co-coordinator, Environmental Justice Health Alliance for Chemical Policy Reform
- Dr. Mildred McClain, executive director, The Harambee House
- The Hon. Harold Mitchell, Jr., executive director, ReGenesis Project; former state representative, South Carolina House of Representatives
- Richard Moore, co-coordinator, Los Jardines Institute
- Dr. Nicky Sheats, Esq., chairperson, New Jersey Environmental Justice Alliance; director, Center for the Urban Environment of the John S. Watson Institute for Public Policy at Thomas Edison State University
- Peggy Shepard, co-founder and executive director, WE ACT for Environmental Justice
- Jumana Vasi, senior advisor, Midwest Environmental Justice Network
- Dr. Beverly Wright, executive director, Deep South Center for Environmental Justice
- Sara Chieffo, vice president of government affairs, League of Conservation Voters
- Jessica Ennis, legislative director for climate and energy, Earthjustice
- Lindsay Harper, representative, U.S. Climate Action Network
- Cathleen Kelly, senior fellow for energy and environment, Center for American Progress
- Lissa Lynch, staff attorney, Natural Resources Defense Council
- Liz Perera, climate policy director, Sierra Club

International central bankers (October 2019)

- Frank Elderson, executive director of supervision, De Nederlandsche Bank; chairman, Network for Greening the Financial System (NGFS)
- Nathalie Aufauvre, director general of financial stability and operations, Banque de France
- Dr. Sabine Mauderer, member of the Executive Board, Deutsche Bundesbank
- Dr. Egil Matsen, deputy governor, Norges Bank

Health Care Climate Council (October 2019)

- Katie Wickman, sustainability manager, Advocate Aurora Health
- Brett Green, manager for remote operations, Ascension Medxcel
- Bob Biggio, senior vice president of facilities and support services, Boston Medical Center
- Jon Utech, senior director, Office for a Healthy Environment, Cleveland Clinic
- Rachelle Reyes Wenger, system vice president of public policy & advocacy engagement, Dignity Health
- Elizabeth Rogers, policy analyst, Gundersen Health System
- Charles Goyette, director of sustainability, Inova Health System
- Jean Garris Hand, senior utility & sustainability consultant, Providence St. Joseph Health
- Michael Waller, director of sustainability, Rochester Regional Health
- Jeanine Knapp, sustainability leader, ThedaCare
- John Leigh, director of sustainability, Virginia Mason Health System

BlueGreen Alliance (December 2019)

- James Slevin, national president, Utility Workers Union of America (UWUA)
- Anna Fendley, director of regulatory and state policy, United Steelworkers (USW)
- Collin O'Mara, president and CEO, National Wildlife Federation
- Kathleen Rest, executive director, Union of Concerned Scientists
- Tiernan Sittenfeld, senior vice president of government affairs, League of Conservation Voters
- Jason Walsh, executive director, BlueGreen Alliance

Insurance industry executives (March 2020)

- Evan Greenberg, chairman and CEO, Chubb
- Mike Mahaffey, chief strategy and corporate development officer, Nationwide
- Melissa Salton, chief risk officer, Munich Re
- Ian Branagan, group chief risk officer, RenaissanceRe

Surfrider Foundation (March 2020)

- Greg Long, pro surfer
- Leah Dawson, pro surfer
- Dr. Cliff Kapono, pro surfer, journalist, and chemist
- Pete Stauffer, environmental director, Surfrider Foundation
- Katie Day, staff scientist, Surfrider Foundation
- Stefanie Sekich-Quinn, coastal preservation manager, Surfrider Foundation
- Vipe Desai, co-founder, Business Alliance for Protecting the Pacific Coast (BAPPC)
- Chris Evans, Surf Industry Manufacturers Association (SIMA)
- Shea Perkins, senior manager for culture & impact marketing, Reef
- Madeline Wade, vice president, Signal Group (on behalf of REI)

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- Request to Native and Tribal communities (July 2019)
- Request to environmental justice leaders (December 2019)
- Request to rural and agricultural communities (May 2020)
- General request for input from climate stakeholders (May 2020)

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Senator Baldwin: Colleene Thomas, Charlotte Benishek

Senator Heinrich: Casey Suchors-Field, Dan Alpert, Maya Hermann

Senator Markey: Georgia Lagoudas, Lindsey Griffith, Hannah Vogel

Senator Duckworth: Radha Adhar, Ridhwan Sediqe, Chelsea McDonald

Senator Cortez Masto: Samantha Swing

Senator Smith: Pete Wyckoff, Emily Beagle, Gabi Rosenfeld, Sade Nabahe

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Democratic Policy and Communications Committee: John Donnelly, Cristina Shoffner

Senate Committee on Indian Affairs: Josh Mahan, Jennifer Romero Monaco

Senate Recording Studio: Luke Gallagher, Carlos Velado

Senate Appointment Desk: Anjunelly JeanPierre, Mele Williams

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