



# America's **ZERO CARBON ACTION PLAN**

# 1. OVERALL POLICY FRAMEWORK

Jeffrey Sachs, Sustainable Development Solutions Network (SDSN)

## 1.1 Goals and Scope

The Zero Carbon Action Plan (ZCAP) aims to put Americans back to work to build a vibrant 21st century U.S. economy based on advanced technologies, good jobs, clean energy, climate safety, and economic security. It is designed to achieve net-zero emissions of greenhouse gases by 2050 as America's contribution to the Paris Climate Agreement to pursue efforts to limit global warming to 1.5°C, a goal later underscored by a special report of the Intergovernmental Panel on Climate Change. It will hold other countries accountable for climate safety as well, ensuring that American industry will not be undercut by polluting competitors abroad.

In this effort, the U.S. will not be alone. The European Union has recently adopted the European Green Deal to achieve net-zero emissions by 2050, and by 50-55 percent as of 2030 compared with 1990. The European Green Deal is backed by a new €750 billion recovery fund, including funds for research and development (R&D) on the new clean energy technologies. China's high-technology program, Made in China 2025, involves massive outlays to propel China's technological advance in key green technologies, including renewable energy, smart grids, electric vehicles, and advanced technologies in rail, shipping and aviation.

The new clean-tech economy will help to save the planet from human-induced climate change while creating millions of good jobs, many more than will be cut in the fossil-fuel industry, and smart federal policies can magnify those favorable job trends. Yet there is currently no strategy at the federal level to support these new job-creating sectors. Private businesses are stymied, not able to invest at scale because the accompanying public investments in infrastructure (e.g., an upgraded national power grid, charging stations on the Interstate Highway for electric vehicles, national connectivity for 5G) have not been made. The U.S. currently spends around \$20 billion annually to subsidize old polluting companies and sectors that have limited long-term prospects, while our competitors in Europe and Asia are building the industries of the future such as photovoltaics, wind turbines, long-distance transmission systems, 5G enabled smart grids, advanced batteries, and others.

We estimate that the clean energy sector and its supply chains will create around 2.5 million net jobs per year on average between 2020 and 2050, taking into account the decline in jobs in the fossil-fuel industries, with many industrial jobs created in America's industrial heartland in the Appalachian region and Midwest. This estimate includes the direct and indirect job creation in the clean-energy economy and subtracts the job losses in the fossil fuel industries. In other words, the shift to clean energy is a net job creator. The new jobs will include the large-scale production and installation of zero-carbon power generation and distribution based on solar, wind, and hydro power, and the manufacture of electric vehicles, batteries, wind turbines and solar panels, green hydrogen and other green fuels, and related technologies. In addition, there will be around 800,000 new jobs per year associated with investments in energy efficiency, such as retrofitting buildings for insulation and electrification.

The ZCAP is based on detailed technological pathways that demonstrate the feasibility of reaching zero emissions by 2050, as well as detailed background analyses of key sectors. These pathways are described in detail in Chapter 2. The pathways cover all regions of the country and all major sectors of our energy system. The action items identified build on technologically and economically sound options and fit within the institutional framework of the U.S. federal system. We believe the policy framework advanced here has both an economic logic and a political appeal that can win majority support with the public throughout the entire country, and at all levels of government: federal, state, and local.

Building a new energy and jobs strategy cannot be left to either the private or public sector alone, and it cannot be a short-term policy. We require clear goals and policies that will enable a long-term transition that will require 30 years to complete. The long-term nature of the transition is the result of one simple fact: greenhouse gas emissions are mainly due to the long-lasting capital stock that as of now relies heavily on fossil fuels: power plants, vehicles, buildings, and factory output. This capital stock will roll over during the next thirty years. The main process of energy-system transformation is to replace the fossil-fuel-using capital stock as it is retired with new zero-carbon capital that depends on clean power and green fuels.

The private sector today is held back by the lack of clear federal policies. Private companies need clear goals, credible incentives, support for research, development, demonstration and deployment (RDD&D) support, and reasonable protection from foreign competitors that use fossil-fuel intensive technologies. It needs supporting regulations for siting new clean-energy projects. It needs public infrastructure that is complementary to private investments. Since the Federal Government has no long-term plans for sustainable 21st century infrastructure and the green transformation of the energy system, the private sector cannot invest at scale. Trillions of dollars of private investments will sit on the sidelines until there is clarity and movement on long-term U.S. energy and infrastructure policies.

Nor can the Federal Government alone provide the needed leadership in our federal system. States and localities must also play key leadership roles. In fact, a number of governors and mayors have already staked out leadership positions on renewable energy and vehicle electrification and have put forward policy innovations that offer important learning and demonstration effects. In addition, the states oversee much of the core energy infrastructure including power plants and roads and bridges.

Even more critically, these subnational governments have jurisdiction over critical regulatory and management functions. Notably, state public utility commissions regulate electric utilities and cities and states establish building codes and thus are positioned to determine the energy efficiency of much of the built environment. Local governments also invest in mass transit and roads, and regulate land use and housing. Further, states and cities have the ability to change more rapidly and can design transition strategies tailored to their local resources and communities. Success, however, will require the backing of the Federal Government with regard to regulatory frameworks, carbon reduction targets, and incentives as well as financing and federal investments. Further, states and cities have the ability to go further faster and can design transition strategies tailored to their local resources and communities.

The Zero Carbon Action Plan centers on the six major energy-producing and using sectors: power generation, transportation, buildings, industry, land use for agriculture, forestry and other purposes, and materials. These six sectors account for almost all of the CO<sub>2</sub> emissions of the U.S. We focus mostly on CO<sub>2</sub> emissions but also note the importance of non-CO<sub>2</sub> greenhouse gas emissions (GHG) including methane, nitrous oxide, and various industrial gases. In fact, CO<sub>2</sub> emissions account for 81 percent of overall U.S. GHG, so any serious plan for climate neutrality by 2050 (that is, zero net emission by 2050), must start with CO<sub>2</sub> emissions.<sup>1</sup>

*The key components required for the new green-growth model include:*

- **Rapid upscaling of renewable energy.** While the shift away from a fossil-fuel-based economy will be challenging, the utility sector is already moving in the right direction and can move far more rapidly and deeply with the right incentives. Indeed, power generation is currently the only major sector that shows signs of shallow decarbonization while nearly all other sectors have flat or rising emissions.
- **Electrification** of the economy wherever electricity-based energy is economically feasible and practical – including in ambient heating and ventilation (both new buildings and retrofits), and light, medium- and even heavy-duty vehicles, including much of trucking (urban delivery, drayage at ports), buses, rail, and some industrial applications – recognizing that the electric sector must fully transition to emissions-free clean power options to deliver the benefits of electrification.
- **Transition to hydrogen, advanced biofuels, and other clean fuels** manufactured with zero-carbon power for “hard-to-abate” existing buildings and industrial sectors such as steel, cement, chemicals, aircraft, and ocean-shipping. Each of these transitions will require a tailored strategy that reflects the technological requirements and industrial organization of the sector.
- **Sustainable forest and agricultural lands** based on large-scale reforestation, increased soil carbon through improved farm practices, next-generation biofuels that do not compete with the food supply or ecological needs, healthier diets with greater reliance on plant-based proteins, and reduced food losses and waste.
- **Reduced material wastes through Sustainable Materials Management (SMM)** industrial processes, reduced utilization of single-use plastics and other polluting goods, advanced materials, and the scale-up of recycling and other components of the circular economy, based on “reduce, recycle, and reuse” materials.
- **Rejuvenation of the industrial heartland** of America in the Appalachian Region and the Midwest to build the wind turbines, solar panels, electric vehicles, advanced biofuels and hydrogen systems, transmission grids, and the smart software for efficiency of the energy system.
- **Government-backed financing, investments, and regulatory support** at all critical stages of the transformation, including for job training in the new sectors; utility financing for rapid scale-ups of renewable power generation and energy efficiency in the residential, commercial, and industrial sectors; industrial restructuring in motor vehicle manufacturing and heavy industry; public infrastructure, including a revamped transmission grid, charging stations for electric vehicles, and advanced public transport services in urban areas; and research and development for cutting-edge zero-carbon technologies;
- **A national RDD&D strategy** (research, development, demonstration & deployment) to ensure that America stays at the technological forefront of the new clean-energy economy, including smart grids and smart homes, distributed generation, advanced renewable power, high-efficiency batteries and other energy storage, fuel-cell technologies, and other areas.

## 1.2 The Overwhelming Case for a Clean-Energy Economy

The U.S. economy is still largely geared to the era of fossil-fuels: electricity produced by fossil fuels (around 63 percent), transport based on petroleum (around 95 percent), buildings heated by oil and gas, industry powered by coal and gas, and so forth.

Meanwhile, the European Union, China, and other countries are increasingly focused on the green technologies of the future. In 2015, all 193 member countries of the United Nations signed the Paris Climate Agreement to pursue efforts to limit global warming to 1.5°C, a goal later underscored by a special report of the Intergovernmental Panel on Climate Change. Only the U.S. has announced its withdrawal from the agreement (effective November 4, 2020), while all other 192 countries have remained. The U.S. risks falling far behind in global competitiveness in the clean-energy sector, especially as China continues with its Made in China 2025 strategy, which focuses heavily on advanced green technologies, and as the European Union implements the newly adopted European Green Deal.

## 1.3 Framework for Large-Scale Change

This plan offers a framework for large-scale change that has four core elements. The first element is *technological*. The American economy requires deep technological changes to continue defining the forefront of new global industries. The strategy of this plan is based on regulations and market incentives to promote high-speed innovation and rapid adoption of zero-emission technologies.

The second core element builds on *American federalism*. Large-scale change must rely on clear national goals, supported by the cooperative efforts of federal, state, and local governments with an appropriate division of labor among the levels of government and between the public and private sectors. The new economic growth model will require both top-down leadership and bottom-up innovation and implementation. Moreover, a strategy based on federalism that actively engages all levels of government will have greater credibility and staying power than a program designed to operate only by top-down policies.

The third core element is *foreign policy*. The U.S. share of global GHG emissions is currently around 15 percent. The world's climate future depends on global actions, not the actions of any one country alone. The new U.S. energy strategy must include a strong foreign policy dimension, so that what happens domestically (and in other countries where serious decarbonization strategies are put into play) is matched and magnified globally. The U.S. must not only rejoin the Paris Climate Agreement, but also help to lead the world toward decarbonization at the needed pace. The U.S. must promote a global trading system that favors innovation and clean-energy technologies and that prevents free-riding by countries that try to shirk their global responsibilities for action.

The fourth core element is *industrial policy* – using the heft of the U.S. government to promote new high-tech industries as has been done successfully in many other areas, including advanced semiconductors, space industry, the Internet, biotech, and other areas of advanced technologies.

The following will consider these four core elements in turn: technological transformation, federalism, foreign policy, and industrial policy.

### 1.3.1 Technological

Looking to history, profound technological changes often begin in niches and then diffuse more widely – ultimately reconfiguring entire markets. This element of the following framework of change means that one must understand, sector-by-sector, the state of play of technology – and the challenges and opportunities that must be addressed. The policy interventions needed will depend on that state of play:

- For early stage technologies, policies that promote broad-based investment in RDD&D will be critical. Indeed, because new ideas are public goods (freely provided to all), testing of a range of new ideas and learning quickly what works is essential. Likewise, it is crucial to the innovation process to take risks and make mistakes but also move quickly to cut losses and double down on successful breakthroughs. Markets for these new technologies may need to be “made” –such as through government procurement, creative financing (e.g., green banks), guaranteed offtake arrangements (e.g., power purchase agreements), and other strategies that provide predictability and revenue flows that make investments in these emerging technologies “bankable.”
- For diffusion and reconfiguration of existing technologies, the policy instruments required will be different because the tasks are different. In more mature areas of technological change, the options are better known and the goal must therefore be to encourage more widespread adoption, additional learning through experience, and ultimate reconfiguration of markets around deep decarbonization. Here the requisite policies will include regulatory requirements including performance standards, carbon pricing, and harm charges more generally. These should be designed to ensure the objective of zero net emissions by 2050 in the most efficient manner.

Big changes in technology will require a major financing effort by both the public and private sectors, combined with clear goals and strong regulations and incentives at all levels of government. Every sector of the energy system is interconnected with the others. Renewable energy will require a modernized power grid to support it. A new electric vehicle industry will require a national supply chain of advanced battery production, as well as charging stations along the nation’s roadways and smart grids working efficiently with the electric vehicle fleet. The massive investments needed in zero-carbon wind and solar power will require that federal, state, and local authorities support access to the required land, consider tradeoffs between renewable siting and priorities in agriculture and local ecosystems, and ensure that low-cost financing is available. In short, the complementary pieces of private investment, public investment, RDD&D, and job training, must all work together.

### 1.3.2 Federalism

The Zero Carbon Action Plan will operate across all levels of government – federal, state and local. Some elements of this policy will be broad-based and cover the whole economy – for example, investments in early stage RDD&D, carbon-emission standards in transportation and electricity, and carbon pricing in some sectors to help point innovation in the right direction – often through hybrid regulatory-market policies such as trading of vehicle emission credits. Most of the leverage will come from detailed actions in specific sectors and locales. The various chapters provide a framework for this action agenda across economic sectors and levels of government.

## Federal Government

The Federal Government must take the lead in setting clear national goals and milestones for all key CO<sub>2</sub> emitting sectors – power, transport, buildings, and industry – to achieve zero net emissions no later than 2050. To achieve those goals, the Federal Government should partner with the best minds in the private sector, NGOs and academia and develop technology roadmaps for each major sector, or to create new programs for rapid learning as in the past successes of the National Aeronautics and Space Administration (NASA), Defense Advanced Research Projects Agency (DARPA), Advanced Research Projects Agency-Energy (ARPA-E), National Institutes of Health (NIH), and the National Science Foundation (NSF).

The sector chapters included within provide a starting point for such technology roadmaps and more open-ended RDD&D programs. In turn, the RDD&D priorities identified should help to guide substantially increased federal outlays on RDD&D for zero-carbon energy technologies. The Federal Government will also invest directly in key parts of the national energy system, including inter-state power transmission, public land use for power generation, and supporting infrastructure. The Federal Government will also engage in innovative green financing, such as government guarantees for green bonds, tax incentives on utility bonds for renewable energy, direct equity, funding of state-level green banks, and others. All of this will be supported by clear mandates for all key federal agencies, including the science agencies (NSF, NOAA, DOE, etc.) and the regulatory agencies (DOT/NHTSA, EPA, Interior, FERC, etc.). Finally, the Federal Government will provide foreign policy leadership, including re-entry into the Paris Climate Agreement, participation in global technology partnerships and standard setting, new financing for low-income countries, and border taxation and regulation for trade in energy-intensive products.

## State Governments

State governments are responsible for power generation and within-state distribution – and play a role in coordinating regional grids. Well over half the states have enacted Renewable Portfolio Standards (RPSs) for their state utilities, typically overseen by public service commissions and departments of energy in the state government. The most important single step will be to adopt a national timeline and goal for net-zero emissions by 2050, implemented through a national clean energy standard, which serves as a framework and “floor” for states to build on their existing RPS goals. Some states will move faster than the federal timeline, and should be encouraged and enabled to do so. Many states have already adopted zero-emission vehicle sales requirements, low-carbon fuel standards for transportation energy, and are currently pursuing more aggressive GHG performance standards for vehicles than the Federal Government. States are working together to develop innovative pricing and investment policies, through collaborations like the Regional Greenhouse Gas Initiative and the Transportation and Climate Initiative. Many states are already committed to timelines to decarbonize electricity generation and transportation before 2050. Incentives need to be established to get other states on the same trajectory.

State governments are also leaders of local economic development initiatives, at the state, regional, or metropolitan scales. State policies will continue to support manufacturing of green technologies, such as solar panels, wind turbines, components for electric vehicles, software and hardware for smart grids, and the like.

State government instruments include public investments, regulation of the utility sector, tax and other incentives for industrial location, transportation planning, design and retrofitting of state buildings and transportation fleet, public transportation policies, state building codes, and public infrastructure (e.g., charging stations on state roads).

## Local Governments

Local governments, like state governments, have often been leaders on climate and sustainability. Local governments also have jurisdiction over urban land use, building codes, roads, transit, and much more. They are on the front lines for many of the changes needed to decarbonize, and are often willing to take the lead on environmental commitments, but generally have limited capacity and resources. The Federal Government can provide resources, for instance to support a transition from single-occupant vehicles to transit and to shared and pooled services in ways that enhance accessibility by disadvantaged travelers. The Federal Government can restructure transportation funding and can empower local governments to decarbonize travel and better organize land uses.

### 1.3.3 Foreign Policy

The Zero Carbon Action Plan must also be incorporated into America's foreign policy and diplomacy for four major reasons.

- First, and foremost, climate safety can be achieved only by a global transformation to net-zero emissions by mid-century. The U.S., for example, emits roughly 15 percent of the total worldwide CO<sub>2</sub> emissions from energy and industry. Even if U.S. domestic emissions achieved the net-zero goal, the CO<sub>2</sub> problem would persist unless there is comparable progress across the globe. The U.S. will best promote action abroad in four ways: remaining at the forefront of new clean-energy technologies, exporting clean-energy solutions, rejoining the Paris Climate Agreement, and insisting that other countries clean up their own energy systems in order to keep their access to the U.S. marketplace
- Second, the pace of the U.S. energy transformation will affect competitiveness in the global market. Other nations, notably the EU, China, Japan, and Korea, are already advancing in high-tech, low-carbon technologies. U.S. companies will need to move faster to maintain their global competitiveness.
- Third, the new U.S. clean-energy industries will need reasonable protection from products overseas by CO<sub>2</sub>-intensive industries. America should deploy a new system of "border tax adjustments" to ensure that fossil-fuel-intensive competitors are not able to take advantage of the new clean-energy industries. Such border adjustment mechanisms are also part of the European Green Deal. Fossil-fuel based American firms will likely face border taxes when exporting to the EU.
- Fourth, the global technological transformation to clean energy will involve new technology standards for vehicles, aviation, ocean shipping, power generation, cross-border power transmission, energy efficiency, smart grids, artificial intelligence, and other parts of the new energy economy. The United States should play a leadership role in setting these new standards.
- Fifth, the U.S. will have to work with other nations to update the global trade and investment rules at the World Trade Organization (WTO) and elsewhere to ensure that the rules and procedures of the international trading system reinforce the global commitment to sustainability in general and decarbonization in particular.

### 1.3.4 Industrial Policy

As the entire world moves towards clean-energy technologies, U.S. competitiveness, national security, and global leadership will depend on its capacity to build world-leading, large-scale industries in each critical part of the new energy system. The U.S. has considerable experience and success with technology-based industrial policy domestically, and it confronts similar policies in foreign relations, most notably in China. The U.S. has successfully promoted major private industries based on public-private technological initiatives. Key industrial sectors for the future include: renewable energy (e.g., photovoltaics, wind power); power transmission and distribution; smart grid with 5G backbone; electric vehicles; advanced batteries at grid, vehicle, and household scale; fuel cells; low-carbon aviation; zero-emission buildings; hydrogen and other zero-carbon fuels such as advanced biofuels; new materials replacing petroleum-based products; carbon-capture and storage; and potentially advanced nuclear power (e.g., modular, fourth-generation, passive safety systems, new fuel cycles, fusion). These technologies will spur further advances in nanotechnologies, new materials, robotics, artificial intelligence, and other systems.

## 1.4 Transformation of Six Key Sectors

Six sectors of the economy account for almost all CO<sub>2</sub> emissions, and most emissions of other greenhouse gases. The key, therefore, is the deep transformation of these sectors by 2050, which may be summarized as follows:

### Power

**Power.** The single most important transformation is the decarbonization of power generation, which accounted for around 32 percent of total CO<sub>2</sub> emissions from energy and industry in 2019 (see Table 1.1). The major shift is to wind and solar energy, with continued production from other zero-carbon sources, notably nuclear and hydropower. For purposes of maintaining electricity system reliability, a substantial fleet of gas-fired power generators needs remain in place in 2050, roughly comparable to today's level of capacity. However, these generators will run much less often than they do at present, comprising only a few percent of total electricity generation. The fuels used in this generation can be made carbon-neutral, or their emissions can be offset elsewhere in the system. Since wind and solar power are already at or near grid parity with coal-fired and gas-fired power generation, inclusive of energy storage, the incremental energy costs compared with business-as-usual (BAU) associated with the green transformation of the power sector are small. As part of decarbonizing the economy, the power sector will need to grow in order to absorb new loads from transportation, buildings, and industry, as those sectors electrify. In order to keep the cost of a larger grid (including generation, transmission, and distribution) affordable nationally, our analysis assumes a 40 percent efficiency improvement in per capita energy use by 2050.

## Transport

The transportation sector includes light-duty vehicles, heavy-duty vehicles (trucks), off-road vehicles, buses, rail, shipping, and aviation. Transportation emissions accounted for 37 percent of total CO<sub>2</sub> emissions from energy and industry in 2019. The principal strategy for decarbonizing transportation is electrification (including battery, plug-in hybrid, and hydrogen fuel cells), including all light-duty vehicles, urban-based trucks and buses, rail, much of long-haul trucking, and some short-haul shipping and aviation. For long-haul aviation and long-haul ocean shipping, advanced low-carbon biofuels and synthetic carbon-based liquids or gases produced with renewable energy are the leading energy contenders. The second strategy is to reduce vehicle use and miles traveled while enhancing accessibility to health, education, jobs, and other services for the mobility disadvantaged, which involves a variety of actions by federal, state, and local governments.

## Buildings

Buildings, both residential and commercial, account for 12 percent of direct CO<sub>2</sub> emissions; this rises to 32 percent when the building share of electricity emissions are taken into account. Buildings built between now and 2050 will comprise 30 percent of the building stock in 2050. A new National Energy Code for Buildings (NECB) should ensure that new buildings constructed after 2025 will not burn fossil fuels onsite, will be highly energy efficient, and will be constructed using low-carbon techniques and materials. The NECB and federal appliance standards should also ensure that replacement equipment and appliances in existing buildings will be energy efficient and largely electrified.

We recommend that around 5 percent of the national RDD&D budget (rather than less than 1 percent today) should be committed to advanced building technologies, building science, and building policies including through joint ventures with National labs and state analogues. Investment in RDD&D should be paired with the development of a national manufacturing policy that would ensure that a large percentage of green building products are manufactured domestically. In addition to funding federal government building retrofits and new builds to meet the national carbon goals, the Federal Government should provide financial resources via grants to states, counties, and cities, for extensive building retrofits. It should leverage its financial tools, such as tax policy and mortgage underwriting criteria, to encourage low-carbon buildings. The Federal Government should also assist state and local authorities in creating policies for reducing GHG emissions from buildings that exceed national policies and policies for compact, low-carbon development.

## Industry

Industry accounts for 20 percent of CO<sub>2</sub> emissions from energy, of which 68 percent are related to energy demands (electricity and heat) and the other 32 percent result from various industrial processes. As such, a relatively large share of industry emissions from light industries such as manufacturing of durable goods, food and textile processing, and even mining and non-ferrous metal production may be avoided by coordinated efficiency improvements, electrification, and decarbonization of electricity generation. Other industries – such as iron and steel, cement, and feedstock chemicals – are of particular interest in a decarbonization context precisely because their conventional production processes entail emissions that are difficult to avoid and their capital infrastructure tends to be long-lived.

Fortunately, even for these sectors, there are technical solutions available such as Carbon Capture and Sequestration (CCS) at industrial facilities, hydrogen, supplementary materials and fillers, and other synthetic fuel replacements and substitutions. Federal and state governments should work together to revise building and infrastructure codes and to create lead markets to incentivize the commercialization of green industrial products.

## **Land use (agriculture, forests, other non-urban)**

Land use policies impact every aspect of the transition to zero greenhouse emissions, including: siting of renewable energy, next generation biofuels, reforestation, soil carbon, and emissions from agriculture and livestock. The complexity of policy choices in this area will require new efforts at RDD&D, new inter-agency planning, and enhanced cooperation of all levels of government with each other and with impacted communities. Key recommendations include the following:

- A new Advanced Research Projects Agency for Land (ARPA-Land) with a focus on soil carbon sequestration, next-generation biofuels, low-carbon animal protein substitutes, reducing food loss and waste, integration of renewable energy with agricultural land use
- A new inter-agency task force on land to coordinate the multiple issues relevant to U.S. lands in the context of deep decarbonization
- The development and use of integrated models to support long-term pathways towards sustainable land use and food systems
- Integrated spatial planning and transparent processes and financing mechanisms for renewable energy project development and transmission infrastructure;
- Financing incentives for agri voltaics and distributed generation, as well as renewables development, on existing structures on agricultural land and contaminated and underutilized sites
- Regulations to address jurisdictional overlaps among state, federal government, regional transmission operators (RTOs), and the ability of one or a few states to veto an interstate expansion to balance regional and local interests
- Policies to assess impacts on host communities and engage impacted communities in the siting process and decisions on compensation
- Development of a national reforestation goal by 2050, supported by various incentive policies and federal acquisition of private lands for reforestation where feasible and useful
- Policies to increase the storage of carbon in agricultural soils built around incentives, monitoring, reporting
- Transformation to next-generation biofuels through increased RDD&D funding, a new low-carbon fuel standard, and new federal procurement standards
- Promoting dietary shifts to foster healthier diets produced by a food system with lower GHG emissions
- Policies to reduce food loss and waste.

## Materials

ZCAP calls for a new national framework for SMM and Circular Economy (CE) based on the pillars of “reduce, reuse, recycle.” Both SMM and the CE will lead to reduced pollution, energy efficiency, and reduced GHG emissions. Specific SMM and CE policies include: mandatory recycling and composting; national bans on plastic bags, polystyrene, and other polluting materials; SMM plans for materials management; green public procurement criteria and targets; restrictions of waste exports; and embrace of Basel Convention standards for electronic recycling.

**Table 1.1** EIA Total U.S. Energy-Related Carbon Dioxide (CO<sub>2</sub>) Emissions 2019.<sup>2</sup>

	Buildings		Industry	Transportation	Power	Source total
	Residential	Commercial				
<b>Sector total (CO<sub>2</sub> million metric tons)</b>	343	254	1,012	1,902	1,619	<b>5,131</b>
<b>Percent total</b>	11.6%		19.7%	37.1%	31.6%	100%

Carbon dioxide (CO<sub>2</sub>) emissions were about 5,131 million metric tons in 2019. The above numbers show the direct emissions from each sector without double counting electricity.<sup>3</sup>

## 1.5 Economic Costs of Reaching Net-Zero Emissions

Despite all of the heated debate surrounding the energy transformation, the ironic fact is that the incremental cost of running the U.S. economy on clean energy as opposed to fossil-fuel energy is very small. The costs of renewable energy for power generation, electric vehicles, electric heating of buildings, and other technologies are already so low that moving from fossil fuels to clean-energy solutions will add very little economic burden. There are various ways to summarize this burden, for example, comparing the annual outlays of a reference energy path to 2050 and a clean-energy path to 2050. On this basis, the annual outlays on the clean energy path are on average 1-2 percent of GDP higher than on the reference path during 2020-2050, a modest incremental outlay. Yet such a calculation overstates the true costs of the transformation since the outlays after 2050 are much lower for the clean-energy economy. To account for this, we can calculate a “levelized” cost of the clean-energy economy versus the fossil-fuel economy. In this alternative calculation, we measure the annual recurrent costs of the energy system plus the annualized capital charges on the installed capital stock (essentially the cost of capital multiplied by the capital stock). We find that as of 2050, the clean-energy economy is only 0.4 percent of GDP more costly per year than the fossil-fuel economy (and lower than that up to 2050). In other words, for less than one-half of 1 percent of GDP, we can shift the energy system to avoid climate disaster. (Another simple way to think about the levelized cost of the energy system is to assume that all energy-system capital outlays are financed with debt. The levelized calculation then compares the annual costs of servicing the energy-sector debt plus annual recurrent costs, measured relative to GDP.)

## 1.6 Setting Goals and Adjusting Course

All great national efforts require bold visions and plans, and the ability to adjust course along the way. President John F. Kennedy declared in May 1961, “I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth.” At the time that Kennedy set this goal, the U.S. had put a single astronaut into space for just 15 minutes. In other words, the bold goal was set before many of the key steps were known or knowable. Kennedy had confidence in America’s engineering and problem-solving abilities. Indeed, he famously declared in a speech the following year: “We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.”

Of course the New Deal also comes to mind. In the Great Depression, President Franklin Delano Roosevelt led the country at a time of mass unemployment and despair, and boldly devised new strategies to confront the crisis. He called for bold action and learning by doing. As FDR famously declared: “The country needs, and unless I mistake its temper, the country demands bold, persistent experimentation. It is common sense to take a method and try it. If it fails, admit it frankly and try another. But above all, try something.”<sup>4</sup>

In the case of reaching zero emissions by 2050, there are pieces of the puzzle that are already solved, but also many that are still to be determined. This task is our generation’s moonshot, but thanks to bold work of many pioneers in recent years, we have much greater knowledge of how we can reach our goals than the American people had in 1961 regarding the moonshot. We must set the goal for mid-century, embark boldly on what we know, and prepare in the spirit of FDR to experiment, learn and adjust course along the way. As demonstrated by this plan, many of the technological solutions are understood but lack the institutional coordination, political support, and market incentives to scale.

We can make three generalizations. First, the most straightforward CO<sub>2</sub> reductions will be achieved in power generation, followed by transport and buildings, with the greatest uncertainties remaining in parts of industry. Second, all sectors face a rising marginal cost of emissions reduction. A substantial proportion of current emissions in each sector can be abated at a low cost (or even at a saving compared with the current situation), but getting the remaining emissions down becomes increasingly costly as we move towards zero emissions. Third, the costs associated with many low-carbon technologies are declining over time, and are likely to continue to decline. As a result, many actions that seem more costly now are likely to become less costly in the future. Fourth, the solutions required to put us on the path to decarbonization by mid-century are fairly well understood throughout the next decade and then diverge in the following decades depending on innovation breakthroughs and unknown market behaviors. This means that there are some clear “no-regrets” steps that we can take in this decade and then expect to learn about the preferred pathways for later steps as our knowledge progresses.

A brief summary is the following. Decarbonizing the power sector (electricity generation and distribution) will be accomplished mainly by shifting power generation from fossil-fuel primary sources to renewable energy sources, notably solar and wind power. The costs of renewable energy, even with storage, have fallen sharply, and are at grid-parity with fossil-fuel-based power in certain contexts.

The shift in energy sources from coal and natural gas to wind and solar power can be achieved economically with high confidence. Nonetheless, there are complex and well-known issues of managing the power grid with a high penetration of renewable energy (including storage of intermittent renewable energy and dispatchability of power during peak loads). Because of these complexities it may even be economical as part of a zero-net emission strategy to retain a small capacity in gas-fired power generation. In short, low-cost emission reduction of 80 percent of power generation is in clear sight, with future learning and technological improvements needed for the remaining 20 percent.

In the case of transport, we are well positioned for a shift from internal combustion engines (ICE) to electric vehicles (EV) for light-duty vehicles, with automotive supply chains in place and plans to roll out an expanding suite of EV models. By the late 2030s, most or all new light-duty vehicles sold must be zero-emission vehicles in order to meet the 2050 timeline. While the auto industry is well prepared to transition from ICEs to EVs, it will involve a major overhaul, with some companies and countries further ahead. The financial markets are embracing this transformation, with EV-leader Tesla the highest-valued automobile manufacturer in the world today, ahead of General Motors, Ford, and Toyota, and a number of EV startups also valued in the billions of dollars, and every major auto company is now rolling out EVs. Of course consumers are also waiting for charging stations and other EV-friendly infrastructure. Incentive pricing will also make a difference, e.g., subsidizing EVs according to the savings on carbon emissions or phasing in taxes of emissions on ICEs, especially as the infrastructure for EVs is expanded.

Electrification of trucking is lagging, but it is now expected that, because of rapidly dropping battery costs, most trucks can also be electrified in the coming decades. California adopted regulations in June 2020 requiring that 75 percent of medium duty trucks and 40 percent of long-haul trucks sold by 2035 must be electric (including plug-in hybrid and hydrogen fuel cell electric vehicles).

More energy-dense fuels, similar to petroleum, are needed for aviation and shipping, as well as some long-haul trucks. These will be the next-generation biofuels and synthetic liquid fuels (e.g., hydrocarbons synthesized from CO<sub>2</sub>, and water using renewable energy). Thus, part of the solution to transport will involve the build-up of a new fuel sector based on hydrogen, biofuels, and synthetic fuels.

We note that reining in and even reducing vehicle use is a key part of achieving massive reductions in greenhouse gas emissions via vehicle electrification. First, the energy used to manufacture EVs and batteries is large (roughly 20 percent of total lifetime emissions of today's EVs). Second, the challenge of electrifying vehicles is much easier and less expensive if fewer vehicles are needed (currently vehicle use is increasing). Third, shifting travel to few vehicles and low-carbon modes is key to enhancing accessibility and mobility to mobility-disadvantaged travelers.

In the case of commercial and residential buildings, it will be relatively straightforward to build highly energy-efficient, zero-emission new buildings by shifting from on-site of heating oil and natural gas, to onsite electrification, and by using more advanced strategies for building insulation, heating, and ventilation. Millions of existing buildings that currently rely on fossil-fuel combustion will also be retrofitted or replaced depending on costs and context. Retrofitting buildings, including retrofitting for energy efficiency, will potentially provide hundreds of thousands of jobs per year, given that there are around 140 million housing units and nearly 6 million commercial buildings in the United States.

The largest challenges will come in a few energy-intensive industries, where fossil-fuels are used either as feedstocks (as in petrochemicals) or for process heating (as in metallurgy), or where CO<sub>2</sub> is emitted as part of material transformation (as in cement). These sectors will require sector-by-sector, and even product-by-product solutions. Some parts of industry, such as niches in metals production, can be electrified. Some part of the petrochemical industry will shift from processing petroleum to synthesizing alternative fuels including hydrogen. Some parts of the industry will close down in a post-fossil-fuel era, and one that has shifted away from single-use plastics. Yet across the industrial sector, alternative materials, new fuels (hydrogen or synthetic fuels), and new production processes will be needed. Perhaps half of the CO<sub>2</sub> emissions from industry, or about 10 percent of current total CO<sub>2</sub> emissions, will require innovative solutions from new technologies.

The ZCAP calls for rapid scale-up of investments in the known areas, including renewable energy generation and transmission, electric vehicles, and zero-emission buildings and retrofits. It also calls for a massive increase of public-private efforts to achieve zero emissions by 2050 in the hard sectors, notably heavy trucking, shipping, aviation, and selected industries. For these sectors, we recommend a mix of industrial policies including: public-private partnerships on advanced technologies; border taxes on embedded CO<sub>2</sub> to protect the use of low-emission technologies in the U.S.; public procurement policies to incentivize zero-emission technologies; and gradually rising taxes on CO<sub>2</sub> emission to incentive the shift from fossil fuels to renewable energy sources and green fuels (e.g., hydrogen, and synthetic fuels).

### 1.6.1 Job Creation and Just Transition

The Zero Carbon Action Plan will create more than 2.5 million net new jobs per year as part of the energy transition. The net job creation is described in detail in Chapter 3. Jobs will be created in installing the new energy systems, in the manufacture of the equipment, and in the investments to raise energy efficiency such as building retrofits. By comparing the investment patterns of the main central scenario and baseline reference scenario, and then using an Input-Output analysis, we can estimate the number of new jobs created net of the jobs that will be lost in the fossil-fuel-related industries. Our estimates take into account the direct job creation in the end-use sectors (such as the manufacture and installation of renewable energy systems) as well as the indirect job creation in the upstream industries that supply intermediate inputs to the end-use sectors.

Public policy at all levels should commit to ensuring that the jobs created through clean energy investments are high-quality in terms of wages, benefits and working conditions.

- Strong labor unions and effective job training programs are both necessary to promote high-quality job opportunities.
- Additional policies are necessary to ensure that women and people of color have equal access to clean energy jobs. Both groups are currently underrepresented in all areas of the U.S. energy sector.

The federal and state governments should enact just transition policies for workers and communities that are currently dependent on the fossil-fuel economy.

- Between 2021 – 2030, about 12,000 workers per year in the coal industry will experience displacement between 2021 – 2030. Between 2031 – 2050, about 34,000 workers in the oil and gas industry will face displacement.
- All displaced workers should receive pension and re-employment guarantees, as well as generous income, retraining and relocation support. The combined overall cost of such a generous program will be modest.
- Fossil-fuel dependent communities should receive major federal and state-level support to reclaim and repurpose land and generate new investment projects, including in a range of clean energy areas.

## 1.6.2 Federal Financing

Federal financing of the energy transition will involve two main categories of outlays:

- Direct outlays in the budget
- Loan guarantees for outlays by others (e.g., investments by private-sector utilities in clean-power generation and distribution).

Direct outlays by the federal government should include the following:

- Research, development and demonstration programs by the Department of Energy, National Science Foundation, Department of Defense, and others;
- Federal investments in infrastructure, including interstate power transmission, charging stations along the Interstate Highway System and other federal roads, and other related investments;
- Federal outlays for a Just Transition Fund, to cover the needs of workers displaced by the decline of fossil-fuel-related sectors, and of communities adversely impacted by the energy transition;
- Federal procurements of low-carbon vehicles, equipment, and buildings for federal use;
- Federal grants to state governments for retrofitting buildings;
- Federal grants to local communities and farmers for reforestation, soil carbon storage, and other sustainable land use practices.
- Federal outlays to support global funding for low-income countries in mitigating and adapting to climate change.

Federal loan guarantees to accelerate private investments in clean-energy systems should include:

- Federal financing of private and public utilities for investments in zero-carbon power generation and distribution;
- Federal financing to support the sales and leasing of electric vehicles;
- Federal financing to support state and local governments in low-carbon infrastructure investments in state and local buildings, local transport, and zero-emission vehicles.

The specific allocations of federal outlays and loan guarantees according to these categories will depend on the pace by which federal, state, and local programs can be designed and implemented. It would be reasonable to assume incremental direct outlays of at least 1 percent of GDP per year during the fiscal years 2021-2025, and incremental loan guarantees of another 1 percent of GDP per year during the period. This would amount to roughly \$500 billion per year in incremental federal financing during 2021-2025, or \$2 trillion during the four-year period.

## 1.7 Recommendations for All Levels of Government

### 1.7.1 Key Federal Actions in 2021

- Rejoin the Paris Climate Agreement and establish a new and stronger Nationally Determined Contribution for U.S. greenhouse gas emissions – including the goal of net-zero GHG emissions by 2050 and an updated interim goal for 2030.
- Adopt a Zero Carbon Action Plan by legislation committing the nation to net-zero GHG emissions by no later than 2050.
- Require a Presidential report to Congress in January 2022 that provides a detailed roadmap to put the country on the path toward carbon neutrality by 2050.
- Invite the Department of Energy, Environmental Protection Agency, Department of Transportation, and other relevant agencies to translate the Zero Carbon Action Plan into intermediate and sector-specific emissions reduction goals and timelines for power, transport, industry, buildings, land use and materials, and a process for updating such goals.
- Establish a White House Office on Climate Change to coordinate federal agency climate-change activities for both mitigation and adaptation, and to the extent authorized by law, direct the development of plans, establish program metrics, track progress, and otherwise oversee these activities.
- Provide funding for the first four years of the ZCAP at a minimum of \$2 trillion and provide long-term mechanisms for adequate future funding, including federal support for state and local actions.
- Enact a national clean energy standard for electricity to reduce emissions compared to the present by at least 60 percent by 2030, 80 percent by 2040, and >95 percent by 2050.
- Accelerate the transition to electric cars, trucks, buses, and other vehicles through the implementation of new vehicle performance standards, expansion of the incentives for zero-emissions vehicle purchases, and investments in electric vehicle charging station infrastructure.
- Establish a mechanism by which states, territories, and tribes specify how they will achieve their specific Zero Carbon Action Plan milestones.
- Make operational through procedural and substantive commitments the principle that environmental and jobs benefits of the energy transition are to be shared equitably in terms of geography, race, gender, and ethnicity – thereby ensuring that disadvantaged communities benefit fully.

- Invest directly in key parts of the national energy system, including inter-state power transmission, public land use for power generation, and supporting infrastructure.
- Launch innovative green financing mechanisms, such as government guarantees for green bonds, tax incentives on utility bonds for renewable energy, direct equity, and funding of state-level green banks.
- Promulgate new Securities and Exchange Commission (SEC) reporting requirements that require disclosure of climate-change-related risks and broader Environmental/Social/Governance impacts.
- Accelerate, intensify, and fully fund research and development for zero-greenhouse-gas emitting technologies, energy efficiency technologies, and carbon removal technologies.
- Clarify the National Environmental Policy Act (NEPA) requirement that all federal action should be undertaken with an eye toward environmental impacts with a directive to each federal agency to exercise its existing powers and duties in a manner that will contribute to the fullest possible extent to the ZCAP agenda and goals.
- Specify a Social Cost of Carbon or shadow cost of carbon to guide policy formulation and regulatory decision-making as well as to serve as the basis for market mechanisms such as clean-energy subsidies, carbon taxes, feed-in tariffs and auctions, and other market-based instruments that will vary by sector and over time.

### **1.7.2 Key State Actions in 2021**

- In line with the National Clean Energy Standard and the associated goal of net-zero emissions by 2050, all states should prepare Renewable Portfolio Standards (RPS) or equivalent Zero Carbon Energy Standards for the goal of zero-carbon power by 2050. Currently 31 states have RPS of which 8 have the goal of 100 percent renewable energy on or before 2050.
- All states should prepare a comprehensive plan for net-zero GHG emissions by 2050 covering transport, buildings, and industry.
- All states should prepare financing strategies to align with new federal funding programs
- States and cities should implement land use policies that promote densification, transit-oriented development, and complete streets.

### **1.7.3 Key Local Actions in 2021**

- Local governments, working in tandem with state and federal agencies, should prepare local plans for net-zero greenhouse emissions by 2050 covering all local sectors.
- Cities and local governments should adopt building codes and practices that encourage or require zero-emission, all-electric buildings so that all new buildings are 100 percent electric and retrofits for existing buildings are actively underway.
- Cities should align incentives and programs for building retrofits with state climate goals and begin efficient retrofit of existing buildings.

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